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MODIFICATION OF THE ECAS REFERENCE STEAM POWER GENERATING PLANT TO COMPLY WITH THE EPA JUNE 1979 NEW SOURCE PERFORMANCE STANDARDS

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August 1980

Prepared for
National Aeronautics and Space Administration
Lewis Research Center
Under Contract DEN 3-107

For
U. S. DEPARTMENT OF ENERGY
Fossil Energy
Office of Magnetohydrodynamics

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1.0 SUMMARY

This report presents the results of a study carried out to modify the conceptual design and performance of the reference coal-fired, conventional furnace electric power generating plant with wet lime sulfur dioxide scrubber, developed during the Energy Conversion Alternatives Study (ECAS; Ref. 7), to comply with the New Source Performance Standards (NSPS), shown in table I, promulgated by the U.S. Environmental Protection Agency in June 1979. It also presents detailed capital cost estimates for the ECAS and modified reference plants in mid-1978 dollars for both 250° and 175° F (394° and 353° K) stack gas reheat temperatures based on the cost estimates developed for the ECAS study.

The scope of the work for this study included

1. Technical assessments of,
   - Sulfur dioxide scrubber system design
   - On-site calcination versus purchased lime
   - Reheat of stack gas: method -- selection preference
   - Effect of sulfur dioxide scrubber on particulate emissions
   - Control of nitrogen oxides
2. Determination of the design changes required for the ECAS reference plant to meet the June 1979 NSPS, modification of the ECAS design appropriately, and side-by-side comparison of the characteristics and costs of the modified and unmodified components.
3. Update of the ECAS reference plant detailed capital cost estimates presented in the ECAS study (Ref. 7) from mid-1975 to mid-1978, and presentation in a format in accordance with the Federal Energy Regulatory Commission (FERC) code of accounts.
4. Development of detailed capital cost estimates for the modified reference plant, based on the costs of the ECAS reference plant.

TABLE I. - RELEVANT SOLID FUEL EMISSION LIMITS FROM THE JUNE 1979 EPA NEW SOURCE PERFORMANCE STANDARDS (Ref. 2)

PARTICULATE MATTER (a) 0.03 lb/10^6 Btu heat input. (There is also a percent reduction of uncontrolled emissions requirement. Compliance with the stated limit, however, assures compliance with the percent reduction requirement). (b) 20 percent opacity (6-minute average) except for one 6-minute period per hour of not more than 27 percent opacity.
SULFUR DIOXIDE (SO_2) (a) 1.2 lb/10^6 Btu heat input and 10 percent of the potential combustion concentration (90 percent reduction). (b) 30 percent of the potential combustion concentration (70 percent reduction) when emissions are less than 0.6 lb/10^6 Btu heat input. (Compliance with both Items (a) and (b) is based on a 30-day rolling average).
NITROGEN OXIDES (NO_x) 0.6 lb/10^6 Btu heat input for bituminous coal. (There is also a percent reduction of uncontrolled emissions requirement. Compliance with the stated limit, however, assures compliance with the percent reduction requirement).

5. Side-by-side comparison of the modified and ECAS reference plant capital costs and costs of electricity.

6. Preparation of a final report detailing the work done.

The five technical assessments were carried out first in sufficient detail to determine their effects on possible plant design alternatives. Exhaustive, detailed technical and economic studies were beyond the scope of work.

Based on the sulfur dioxide scrubber system design assessment, it was concluded that the modified reference plant should be designed for 90 percent reduction of uncontrolled sulfur dioxide emissions of 8.3 lb $SO_2/10^6$ Btu heat input, corresponding to a coal having a design sulfur content of 4.5 percent and heat value of 10,788 Btu/lb. These parameter values are the same as those employed in the ECAS reference plant. It was also concluded that the plant should be designed to burn two alternate coals with the properties shown in table II. The first corresponds to that used in the ECAS study (Ref. 7), the second to that used in the ETF study (Ref. 5).

Based on the technical assessment of on-site calcination versus purchased lime, it was concluded that neither on-site lime production, which was included in the ECAS study, nor the purchase of lime from an off-site manufacturer should be included in the modified reference plant design. The on-site lime production and purchased lime alternatives were both determined to be more expensive than direct limestone utilization. Wet limestone scrubbers, therefore, were substituted in the modified reference plant for the wet lime scrubbers included in the ECAS reference plant. This design change decreased the cost of the SO_2 scrubber system and reduced the coal input rate to the plant by the amount required for the on-site lime production, resulting in an approximately 0.5 percent increase in plant efficiency.

Seven alternatives for the method of stack gas reheat were considered for use in the modified reference plant. These were:

TABLE II. - SELECTED PROPERTIES OF ILLINOIS NO. 6 BITUMINOUS COALS USED FOR DESIGN OF THE MODIFIED REFERENCE PLANT

Properties	Primary Coal (1)		Alternate Coal (2)	
	Mean	Standard Deviation	Mean	Standard Deviation
Proximate Analysis (As Received), % (wt)				
Moisture	13.0	1.1	8.9	1.1
Volatile Matter	36.7	1.7	38.0	1.1
Fixed Carbon	40.7	2.0	41.7	1.0
Ash	9.6	0.9	11.4	1.1
Ultimate Analysis (As Received), % (wt)				
Sulfur	3.9	0.3	3.3	0.6
Hydrogen	5.9	0.1	5.4	0.1
Carbon	59.6	1.2	62.4	0.6
Nitrogen	1.0	0.05	1.2	0.02
Oxygen	20.0	1.2	16.3	0.9
Ash	9.6	0.9	11.4	1.1
Higher Heat Value (As Received), Btu/lb	10788	216	11265	135
Coal Rank	HVCB	-	HVCB	-
Ash Analysis, % (wt)				
SiO_2	46.6	6.1	41.4	5.4
Al_2O_3	19.3	6.8	19.3	6.8
Fe_2O_3	20.8	6.3	22.3	6.8
TiO_2	0.8	0.3	0.9	0.3
P_2O_5	0.24	0.1	0.12	0.04
CaO	7.7	4.7	5.4	3.3
MgO	0.9	0.7	1.7	1.3
Na_2O	0.2	0.1	0.6	0.2
K_2O	1.7	0.3	2.1	0.4
SO_3	2.4	0.2	7.5	0.6
Initial Deformation Temp., °F (°K)	2050 (1394)	70 (39)	1960 (1344)	70 (39)
Softening Temp., °F (°K)	1979 (1355)	68 (38)	2030 (1383)	70 (39)
Fluid Temp., °F (°K)	2265 (1514)	175 (97)	2260 (1511)	200 (111)
Grindability, H.G.I.	54	2	54	2

(1) Corresponds to the coal used in the ECAS study (Ref. 7).

(2) Corresponds to the coal used in the ETF study (Ref. 5).

(1) in-line (direct steam-flue gas heat exchange), (2) indirect (steam-air-stack gas heat exchange), (3) combined indirect and in-line, (4) direct combustion (using oil), (5) flue gas bypass, (6) waste heat recovery (combustion gas-air-stack gas), and (7) no reheat. Each alternative was eliminated in favor of the indirect (steam-air-stack gas heat exchange) method ("method 2" used in the ECAS reference plant).

In-line reheat components (method 1), and the in-line portions of combined indirect/in-line systems (method 3) were noted to be susceptible to corrosion and solids deposition. Their rehability was therefore expected to be lower than that of indirect reheat.

A variation of in-line reheat was also briefly considered in which the in-line component was split into a part constructed of a more expensive corrosion resistant alloy and a part constructed of a less expensive carbon steel. The alloy part would be placed just downstream of the scrubber, where condensation and acidic attack would be most severe, and provide initial superheat of the flue gas before it reached the less resistant carbon steel part. Some success of this method was noted, but since its long-term reliability was not proven it was eliminated.

Direct combustion utilizing oil (method 4) was noted to be not in accordance with the Fuel Use Act and national policy to reduce the use of oil. It was also noted that the method was expected to be relatively more expensive than the indirect method in view of the increases in the price of oil expected in the future.

Flue gas bypass reheat (method 5) was noted to require separate treatment of the bypassed gas before it was discharged to the atmosphere. Thus, it did not provide any advantages over indirect reheat of the total flue gas.

Waste heat recovery (method 6) using heat extracted from the combustion gases just upstream of the boiler air preheater was noted to be promising for the future. However, insufficient

information was available to assess its impact on the air preheater design, operation and cost, the operating temperatures downstream of the air preheater, the boiler efficiency and the overall reliability of the plant.

The last method considered, no reheat (method 7), was also noted to be promising for the future. Since it eliminates the need to divert energy from the power cycle, it is very attractive. However, it requires a significant modification of the exhaust stack configuration and materials compared to a stack preceded by reheat. A few plants were noted to have been built employing the method, but they all included a provision for installing reheat should it become necessary. This indicated the current lack of confidence in the long-term reliability of the method and made it less attractive than indirect reheat.

Based on the assessment of the effect of the sulfur dioxide scrubber on particulate emissions it was concluded, for the purposes of this study, that current wet scrubber designs were adequate to meet the June 1979 New Source Performance Standards for the design coal. The scrubber effects were noted to be due primarily to the effectiveness of the mist eliminator. At the time the New Source Performance Standards were promulgated, the EPA indicated that it was of the opinion that wet scrubber particulate emission could be made to comply, but the data were not conclusive and required further study. Acid mist carryover, however, created by the emission of moisture and the residual SO_2, SO_3 and NO_x allowed by the June 1979 NSPS, and not currently subject to any emission limitation, was noted to be a possible problem in the future. Acid mist carryover affects accurate monitoring of the particulate emissions. The EPA was noted to have recently proposed that a major emissions source, such as the coal-fired plant in this study, which emits more than one tone of sulfuric acid mist per year be subject to EPA approval that the best available control technology has been employed in the plant design. In addition, if the source exceeds 1 $\mu g/m^3$ 24-hour ground level sulfuric acid mist concentration, a detailed

ambient air quality analysis would be required. Since these restrictions were only in the proposal stage at the time of this study, their affects on scrubber design or cost, if any, were not included.

Based on the assessment of the control of nitrogen oxides, compliance with the 0.6 lb $NO_2/10^6$ Btu heat input June 1979 NSPS emission limit was concluded to be achievable with design changes internal to the boiler furnace, made by the boiler manufacturer. These changes provided by one manufacturer, were noted to include redesign and reorientation of the burners to provide a larger combustion zone and more uniform mixing to prevent the formation of high temperature regions where NO_x would be generated. They also were noted to permit operation with a stoichiometric fuel/ air mixture, which was in accordance with the staged combustion technique referred to in the ECAS study (Ref. 7). Staged combustion with reduced excess air, as referred to in the ECAS study, was noted to be basically a variation of the technique included in this study, since it also extends the combustion zone to make it more uniform by turning down the fuel flow to the upper combustor burners, increasing it to the lower ones and at the same time increasing the air flow to the upper burners. Partial combustion takes place at the lower burners and completion at the upper ones. Since the NO_x techniques included in the ECAS and this study were similar, no incremental cost differences were included for the boiler in this study compared to that in the ECAS study.

2.0 INTRODUCTION

In December 1976, the National Aeronautics and Space Administration (NASA) released the results of a "Conceptual Design and Implementation Assessment of a Utility Steam Plant With Conventional Furnace and Wet Lime Stack Gas Scrubbers" (Ref. 1) as part of the Energy Conversion Alternatives Study (ECAS). The ECAS study was undertaken by NASA for the National Science Foundation and Department of Energy (called the Energy Research and Development Administration at the time), and had as its primary objective, the identification and comparison, on an equivalent basis, of national options for the future generation of electricity from coal and coal-derived fuels. Since the ECAS study focused on advanced concepts such as magnetohydrodynamics (MHD) for the conversion of heat to electricity, the conventional furnace plant provided a reference for comparison.

Among the guidelines specified for the plant designs included in the ECAS study were several controlling ones pertaining to the protection of the environment as required under Section 111 of the Clean Air Act of December 1971. Under Section 111, the Environmental Protection Agency (EPA) issued standards of performance to limit emissions of sulfur dioxide (SO_2), particulate matter and nitrogen oxides (NO_x) from new, modified and reconstructed fossil-fuel-fired steam generators (Ref. 1). Those standards, revised in 1973-74, were in effect at the time of the ECAS study, and formed the basis upon which the design of the advanced concept and conventional furnace plants were based.

About three years later in August 1977, President Jimmy Carter signed into law the Clean Air Act Amendments of 1977. Under Section 111(b)(6) of the amended Act, the EPA was required to further revise the standards of 1973-74, and on June 11, 1979 a revised set of standards (Ref. 2) was promulgated.

Based on the revised standards, the ECAS conventional furnace plant was no longer in compliance and could not be used as a reference with confidence. The work presented in this report, therefore,

was commissioned by NASA to modify the ECAS reference plant design to meet the EPA June 1979 New Source Performance Standards (NSPS), revise the detailed cost estimates for the construction of the plant developed during the ECAS study, and provide an up-to-date reference with which to compare current advanced concept plant designs.

The body of this report is divided into nine numbered sections. Six lettered sections follow as appendixes. Sections 1.0 and 2.0 are comprised of these introductory remarks and a summary of the study work included, respectively.

Section 3.0 discusses the criteria and guidelines specified for the study. Among them are the EPA June 1979 New Source Performance Standards, just mentioned, and the site and fuel characteristics. The fuel characteristics are further discussed in section A1.0, which presents a technical assessment of the sulfur dioxide scrubber system capability required to meet the EPA June 1979 NSPS using the coal characteristics selected. To provide reliability (and generality), the plant is designed to utilize two coals, one corresponding to that specified for the ECAS study (Ref. 7) and the other corresponding to that specified for the MHD engineering test facility (ETF) conceptual design study (Ref. 5). In addition, section 3.0 also discusses the detailed capital cost presentation format and the calculation of the cost of electricity guidelines provided by NASA. The former corresponds closely to that used in the ETF study.

Section 4.0 discusses the plant description which is fundamentally the same as that employed in the ECAS study (Ref. 4). Because of this similarity, much of the descriptive information included is extracted directly from the ECAS study. The two flue gas reheat temperatures, 250° and 175° F (394° and 353° K), considered in the ECAS study, are also considered in an equivalent manner in this study. The possible methods available for achieving the required flue gas reheat and the one selected for inclusion in the modified plant design are discussed in section A3.0. One

significant difference is the deletion of on-site lime production from the plant design in this study. The reasons for this are discussed in section A2.0, which presents a technical (and semi-quantitative economic) assessment of on-site calcination (lime production) compared to purchased lime.

Section 5.0 discusses the major plant components and characteristics. Included are the steam turbine-generator, steam generator, particulate scrubber and sulfur dioxide scrubber. As in section 4.0, because of the required equivalence and resultant similarity of the modified reference plant with the ECAS reference plant, much of the descriptive material presented is extracted from the ECAS study (Ref. 7). Section 5.5 presents a comparison of the components of the ECAS and modified reference plants to illustrate the differences in their component characteristics and costs side by side. The two reheat temperature cases are included. All the balance-of-plant costs shown are in mid-1978 dollars.

Section 6.0 briefly discusses the performance of the modified reference plant with respect to the steam cycle (gross power) output; breakdown of auxiliary losses; net plant power output, heat rate and efficiency. An approximately 0.5 percent increase in the modified plant efficiency is noted due to deleting on-site lime production.

Section 7.0 presents the detailed plant capital cost estimates. Cost estimates for the ECAS reference plant - 250° F (394° K) reheat (table X), ECAS reference plant - 175° F (353° K) reheat (table XI), Modified reference plant - 250° F (394° K) reheat (table XII), and Modified reference plant - 175° F (353° K) reheat (table XIII) are included. All costs are in mid-1978 dollars. Also included in this section is a discussion of an illustration showing the cost accounts associated with the major plant components.

Section 8.0 presents a comparison of the detailed capital cost estimates as of mid-1978 for the ECAS and modified reference plants. Both the 250° and 175° F (394° and 353° K) stack gas reheat temperatures are included side by side. Also included is a side by side

comparison of the ECAS reference plant costs as of mid-1975 and mid-1978.

Section 9.0 concludes the numbered sections with a list of references used during the execution of the study.

Appendix A presents five critical technical assessments which form the basis of the modified plant design. Included are discussions of the sulfur dioxide scrubber system with respect to design sulfur removal capacity, on-site calcination process versus purchased lime, reheat of stack gas methods, effect of the sulfur dioxide scrubber on particulate emissions and control of nitrogen oxides.

Appendix B presents the escalation method employed to update the detailed costs of the ECAS reference plant developed during the ECAS study (Ref. 7).

Appendix C presents the original detailed cost tables as of mid-1975 that were developed during the ECAS study (Ref. 7) and that form the basis of this study.

Appendix D presents, for comparison, the ECAS and modified reference plant design parameters.

Appendix E presents the detailed capital cost estimates for the ECAS reference plant, as of mid-1975, recast in the format required for this study from the tables presented in Appendix C.

Appendix F concludes the appendix sections with a list of references used in their preparation.

3.0 CRITERIA AND GUIDELINES

The criteria and guidelines for carrying out this study were specified by NASA. In general, they can be grouped into four subject areas

1. EPA June 1979 New Source Performance Standards (NSPS)

2. Site Characteristics

3. Fuel Characteristics

4. Detailed Plant Capital Cost Presentation Format

A discussion of each of these areas is presented in the following sections.

3.1 EPA June 1979 New Source Performance Standards

Table I lists the applicable solid fuel emission limits extracted from the June 1979 New Source Performance Standards (NSPS). Those which are specifically relevant to bituminous coal, which was specified by NASA to be the fuel for the modified reference plant, consistent with the fuel specified in the ECAS (Ref. 4) and ETF (Ref. 5) studies, are included. The characteristics of the particular coals selected for this study are discussed in section 3.3.

3.2 Site Characteristics

As in the ECAS study (Refs. 4 and 7), the site specified for this study was near the city of "Middletown, USA." To provide a more refined definition, for the purpose of determining the escalation factors (see Appendix B) used to update the ECAS study costs, the location of Middletown was further restricted to the North Central Region of the country.

The following hypothetical site description, extracted from the reference in which it first appeared (Ref. 6), presents the major site characteristics, as modified for this study

> "The site is located on the east bank of the North River at a distance of twenty-five miles south of Middletown, 250,000 population, the

nearest large city. The North River flows from north to south and is one-half mile (2600 feet) wide adjacent to the plant site. A flood plain extends from both river banks an average distance of 1/2 miles, ending with hilltops generally 150 to 250 feet above the river level. Beyond this area, the topography is gently rolling, with no major topographical features. The plant site itself extends from river level to elevations of fifty feet above river level. The main turbine-generator building and the switchyard are located on level ground at an elevation of eighteen feet above the mean river level. This elevation is ten feet above the 100-year maximum river level, according to the U.S. Army Corps of Engineers studies of the area.

"Highway access is provided to the site by five miles of secondary road connecting to a state highway. This road is in good condition and needs no additional improvements. Railroad access is provided by a railroad spur which intersects the B&R Railroad. The length of the required spur from the main line to the plant site is assumed to be five miles in length. The North River is navigable throughout the year with a forty-foot wide channel, 12 feet deep. The distance from the shoreline to the center of the ship channel is 2000 feet. All plant shipments are made overland except that heavy equipment (such as the generator stator) may be transported by barge. The Middletown Municipal Airport is located 3 miles west of the State highway, 15 miles south of Middletown, and 10 miles north of the site.

"The site is in an area of low population density. The nearest residence to the plant is on the opposite bank of the North River, directly west of the main building location, 2600 feet west of the plant boundary.

"There are five industrial manufacturing plants within 15 miles of the site. Four are small plants employing less than 100 people each. The fifth, near the airport, employs 2500 people. Closely populated areas are found only on the centers of the small towns so the total land area used for housing is small. The remaining land, including that across the river,

is used as forest or cultivated crop land, except for railroads and highways.

"Utilities for the site are available as follows:

- The North River provides an adequate source of raw makeup water at 75°F. The average air temperature is: Wet bulb, 51.5°F; dry bulb 59°F. The average relative humidity is 60%. (These values allow the turbine backpressure to be specified as 2.3 inches Hg. absolute).

- Natural gas service is available two miles from the site boundary on the same side of the river.

- Communication lines are furnished to the project boundaries at no cost.

- Power and water for construction activities are available at the southwest corner of the site boundary.

- An emergency power source is required at the plant, since the distribution system in the area is a single source transmission, and is subject to occasional outages.

"According to Weather Bureau records at the Middletown Airport, located ten miles north of the site on a low plateau just east of the North River, prevailing surface winds are predominantly southwesterly 4 - 10 knots during the warm months of the year, and westerly 6 - 13 knots during the cool months. There are no large daily variations in wind speed or direction. Observations of wind velocities at altitude indicate a gradual increase in mean speed and a gradual veering of the prevailing wind direction from southwest and west near the surface to westerly and northwesterly aloft.

"Soil profiles for the site show alluvial soil and rock fill to a depth of eight feet; Brassfield limestone to a depth of 30 feet; blue weathered shale and fossiliferous Richmond limestone to a depth of 50 feet; and bedrock over a depth of 50 feet. Allowable soil bearing is 6000 psf and rock bearing

> characteristics are 18,000 psf and 15,000 psf for Brassfield and Richmond strata, respectively. No underground cavities exist in the limestone."

3.3 Fuel Characteristics

Table II lists the properties of the Illinois No. 6 bituminous coals selected for the design of the modified reference plant. Two coals from nearby sources are specified consistent with usual utility practice of providing a guaranteed fuel supply throughout the life of the plant. As noted, at the bottom of the table, the primary coal corresponds to that used in the ECAS study (Ref. 7), whereas the alternate coal corresponds to that used in the ETF study (Ref. 5). The mean values listed are the same as those appearing in the ECAS and ETF studies. The standard deviations, however, are calculated from the characteristics of actually occurring Illinois No. 6 coals, as discussed in section A1.0.

It may be noticed that the mean ash content listed for the primary coal is the same as the design value used on the ECAS study (Ref. 7) for specifying the particulate emissions reduction required. This does not influence the results of this study, since the alternate coal in this study has higher mean and design values than those for the primary coal and controls the design of the modified plant for particulate emissions reduction.

3.4 Detailed Capital Cost Presentation Format

Table III illustrates the format used to present the plant capital cost estimate details presented in section 7.2. NASA identifies it as the "DOE Code of Accounts - Fossil (Steam) Plant With FGD." It closely resembles the relevant parts of the code of accounts employed in the "Engineering Test Facility (ETF) Design Report" (Ref. 5), prepared for the Department of Energy in June 1978, which presents a capital cost estimate for a magnetohydrodynamic power generating plant.

The following briefly describes the significance of each of the column entries

TABLE III. - FORMAT USED FOR THE PRESENTATION OF THE DETAILED CAPITAL COST ESTIMATES

Column Number									
1	2	3	4	5		6	7	8	9
				Material Costs /dol					
FPC Account Number	ECAS Report Identity	Account/Subdivision	Description/Specification	Major Component	Balance of Plant	Installation Cost/ dol	Indirect Cost/ dol	Contingency Allowance / dol	Total Cost/ dol
310.	-	LAND AND LAND RIGHTS	Not included in study.	-	-	-	-	-	-
311.	-	STRUCTURES AND IMPROVEMENTS	Total Account 311.	-	11,341,000	10,607,250	9,550,220	6,300,000	37,798,000
311.1	7.0	Improvements to Site	Total Subdivision 311.1	-	1,420,000	3,043,250	2,740,220	1,441,000	8,644,000
311.11	7.1	Site Preparation and Improvements	Soil testing, clearing and grubbing, rough grading, finish grading, landscaping	-	10,000	1,022,250	920,460	391,000	2,343,000
311.12	7.2	Site Utilities	Storm and sanitary sewers, non-process service water	-	50,000	58,750	52,900	32,000	194,000
311.13	7.3	Roads and Railroads	Railroad spur, roads, walks and parking areas	-	740,000	317,250	285,660	269,000	1,611,000
311.14	7.4	Yard and Plant Fire Protection, Fences and Gates	-	-	600,000	611,000	550,160	352,000	2,113,000
311.15	7.5	Water Treatment Ponds	Earthwork, pond lining, off-site pipeline	-	20,000	1,034,000	931,040	397,000	2,382,000
311.3	-	Main (Turbine-Generator) Building	Total Subdivision 311.3	-	2,533,000	1,926,000	1,734,000	1,219,000	7,312,000
311.31	5.1,5.3	-	Excavation, substructure, de-watering and piling, including excavation and substructure for transmission plant switch-yard	-	-	-	-	-	-
311.32	5.2	-	Building structure and services	-	-	-	-	-	-
311.4	-	Steam Generator Building	Total Subdivision 311.4	-	5,972,000	4,727,000	4,256,000	2,991,000	17,946,000
311.41	5.1,5.3	-	Excavation, substructure, de-watering and piling	-	-	-	-	-	-
311.42	5.2	-	Enclosure structure and services	-	-	-	-	-	-

Column 1 lists a reference number for each account or subdivision. It is of note that the account numbers (310., 311., 312., 314., 315., 316. and 350.) and their corresponding titles, listed in Column 3, conform to the numbers and titles specified in the uniform systems of Federal Energy Regulatory Commission (FERC) electric plant accounts (Ref. 8) (formerly called the Federal Power Commission (FPC) accounts). These accounts provide a consistent overall framework, recognized throughout the utility industry, for designating the systems and components in an electric plant investment cost estimate or operating financial report. It is also of note that the numbers assigned to the account subdivisions (i.e., 311.1, 311.11, 311.3, 311.4, etc.) in this study can also be generally traced to the FERC guidelines (Ref. 8). However, since the FERC guidelines specifically list only the contents of the accounts, and not the numbering or ordering of their subdivisions, the numbering and ordering of the subdivisions is discretionary. In this study therefore, the subdivisions conform to those listed in the "DOE Code of Accounts," with a few minor alterations and additions, as requested by NASA.

Column 2 lists reference identification numbers from the ECAS report (Ref. 7) to permit locating the tables on which the descriptive and cost data for each account or subdivision are based. For the modified plant tables, identification number(s) of components or systems which are altered with respect to those in the ECAS reference plant are followed by the letter M.

Column 3 lists the title of each account or subdivision as noted in the discussion of the Column 1 entries.

Column 4 lists a description or specification of the equipment, as presented in the ECAS report or as revised for the modified plant, for each component or system comprising an account or subdivision.

Column 5 lists the estimated cost of materials for each account or subdivision and is broken into two parts: Major Component and Balance-of-Plant. Major component costs are those for major purchased items which are engineered, designed, fabricated, shipped, and in some cases, erected by one supplier or manufacturer. Balance-of-plant costs are those for all components (other than major ones), miscellaneous materials, etc., which are assembled and erected on-site.

Column 6 lists the estimated total direct installation cost for the components in each account or subdivision. The ECAS reference plant costs, as of mid-1975, are based on the direct field labor manhour (MH) estimates presented in the ECAS report (Ref. 7), which are converted to mid-1975 dollars employing the relation, given in that report, that 1 labor MH = $11.75 (Ref. 7, p. 33).

Column 7 lists the total indirect construction cost assignable to each account or subdivision. This cost is computed to be about 90 percent of the total direct installation cost listed in Column 6, as in the ECAS report, and includes such items not conveniently charged directly to a single estimating account as wage related costs (overtime, late time, lost time due to inclement weather, paid holidays, paid absences, sick time, etc.); payroll taxes, insurance and bonds; construction equipment and small tools; construction facilities; expendable supplies; and field hire nonmanual labor. For the ECAS reference plant, this cost amounts to $10.58 per labor MH, as of mid-1975.

Column 8 lists the contingency allowable provided for each account or subdivision to allow for additional equipment that might result from a more detailed design of a definitive project at an actual site. Items such as unusual site condition and construction problems, minor scope changes, incomplete designs and estimate revisions are included. A contingency

rate of 20 percent, as in the ECAS report (Ref. 7), is applied to the sum of the major components, balance-of-plant, installation and indirect costs of each account or subdivision. The location of applying the contingency factor, however, is different between the ECAS and the present study. In the ECAS accounting format, the 20 percent contingency rate was not applied to each cost item, but it was applied to the sum of the total plant cost (exclusive of escalation and interest during construction) including 15 percent architect and engineering (A/E) fee. In the ECAS, therefore, the effective A/E fee rate, after the 20 percent contingency rate was applied, was 18 percent. In the format of the present study as shown in table III, the A/E fee is not affected by the 20 percent contingency rate on the contrary to the ECAS format. To maintain consistency between the total plant costs for the two studies, an increased A/E fee rate of 18 percent was used in this study.

3.5 Calculation of Cost of Electricity

The relationship used for calculating the levelized cost of electricity ($\overline{COE}$) was provided by NASA. It represents the plant life cycle costs in terms of an equivalent uniform annual cost over the life of the plant, and consists of three terms which account for the amortization of the total plant capital cost, the levelization of the fuel costs and the levelization of the operation and maintenance (O&M) costs.

The formula for $\overline{COE}$, expressed in mills/kWh, was provided by NASA as follows

$$\overline{COE} = (CAP \times FCR/8760 \times CF \times P) + (FUEL \times 341.2/n) \times LEV + (O\&M) \times LEV$$

where

CAP total plant capital cost at the end of construction, de-escalated to mid-1978

FCR fixed charge rate (= 0.18)

CF capacity factor (= 0.65)

P net plant power output at 100 percent operation (MW)

FUEL fuel price in mid-1978 dollars (= $\$1.05/10^6$ Btu)

n overall plant efficiency (percent)

LEV levelizing factor for fuel and O&M (= 2.004)

O&M operation and maintenance cost (mid-1978 mills/kWh)

The levelizing factor (LEV) is defined as

$$LEV = CRF(r,N)/CRF(k,N)$$

where

CRF capital recovery factor

r interest rate per year (= 0.10)

N plant life (= 30 yr)

e general escalation rate per year (= 0.065)

$$CRF(r,N) = r(1 + r)^N/\left[(1 + r)^N - 1\right]$$

$$CRF(k,N) = k(1 + k)^N/\left[(1 + k)^N - 1\right]$$

$$k = (r - e)/(1 + e)$$

For the purposes of this study, the fuel price escalation rate is assumed to be the same as the general escalation rate. Hence, no further adjustment is included for any differences between these two rates.

4.0 PLANT DESCRIPTION

The modified reference plant description is the same as that of the ECAS reference plant with one exception. On-site lime production is not included for the reasons discussed in section A2.0. Limestone is used for wet sulfur dioxide scrubbing directly. Consequently, all of the equipment and facilities associated with the operation and maintenance of the calciner in the ECAS reference plant are deleted from the modified reference plant. Also, the lime slurry sulfur dioxide scrubbers included in the ECAS reference plant are deleted and limestone slurry scrubbers are substituted in their place. Based on a discussion with a scrubber manufacturer, the differences occurring in the basic construction of the wet limestone scrubbers compared to the wet lime scrubbers were not felt to be significant to the level of accuracy of this study. The following plant description is, for the most part, adopted from the ECAS report (Ref. 7).

4.1 Cycle

A simplified cycle schematic is presented in figure 1. It shows the major pieces of equipment included in the plant. The coal and air are fired using properly designed burners, as discussed in section A5.0, to limit generation of NO_x. The boiler, steam turbine, condenser, and cooling towers are all proven conventional elements. After passing through the electrostatic precipitators that reduce its burden of fly ash, the flue gas enters the sulfur dioxide scrubber and is quenched to 125° F (325° K) with limestone slurry sprays. The sulfur is removed as calcium sulfite and calcium sulfate, which precipitates out in the sludge pond. Water-vapor-saturated flue gas at 125° F (325° K) leaves the scrubber and is reheated to the final stack temperature. In this study, two stack temperatures were studied: 250° and 175° F (394° and 353° K). The means of reaching these temperatures is by blending the treated flue gas with a large quantity of air that has been preheated above the required temperature with steam extracted from the steam turbine cycle.

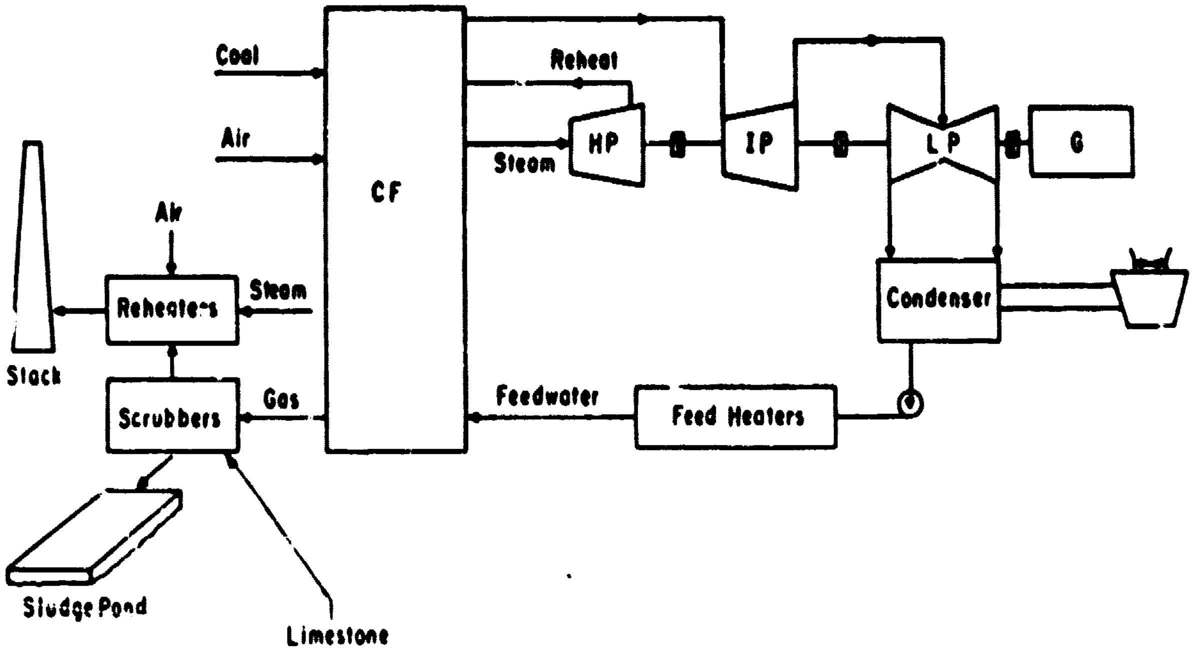
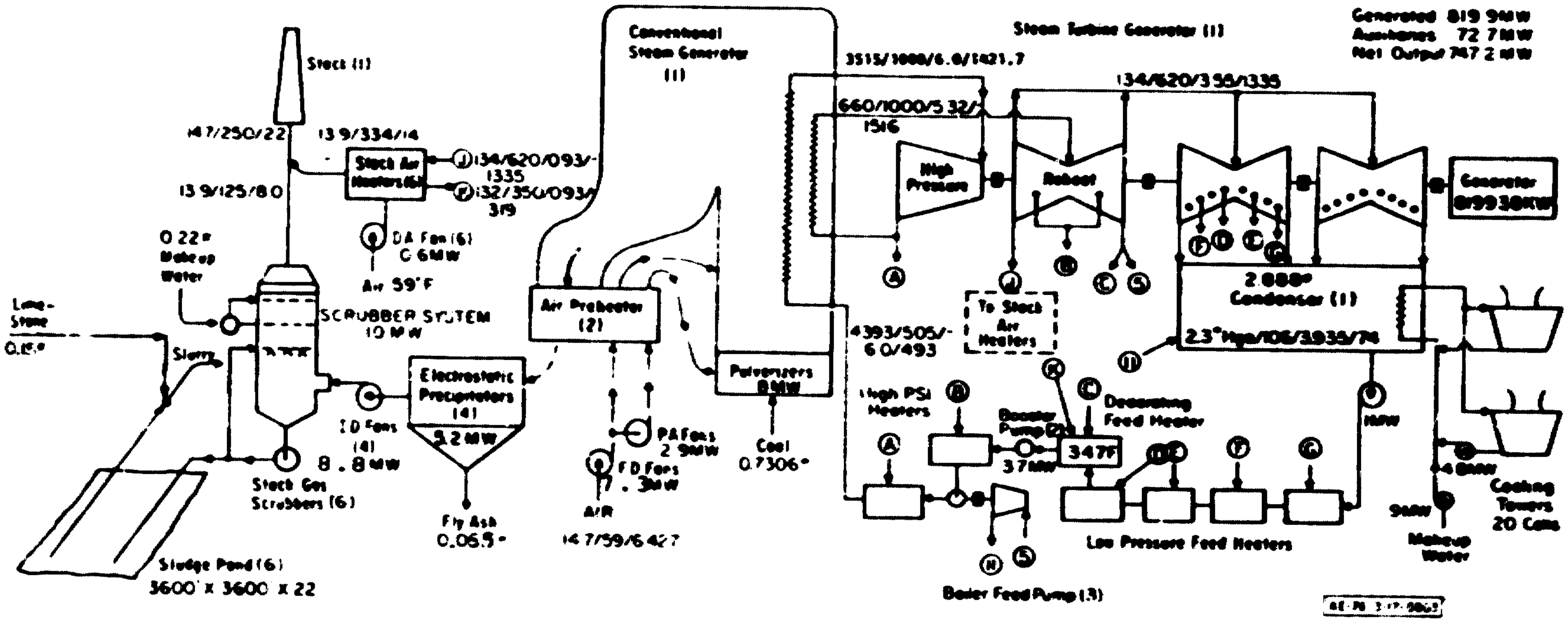


Figure 1. - Simplified Cycle Schematic (Based on Fig. 1, Ref. 7).

The steam cycle is based on conditions for a supercritical reheat unit with seven feedwater heaters. The large extraction of steam at the turbine crossover pressure for the stack gas reheat approaches the limit set for conventional practice. The condenser back pressure was chosen to optimize the total cost of electricity with respect to turbine output and cost, heat rejection system cost, and auxiliary power consumption.

One stack gas reheat temperature case was studied at 250° F (394° K) in conformance with conventional steam power plant practice. The influence of stack gas temperature, however, is significant for this steam plant configuration. Since corrosive component dew points in the flue gas were expected to be no more than 125° F (325° K), as a result of the scrubbing process, a lower reheat temperature of 175° F (353° K) was also studied.

Figure 2 presents a more detailed schematic of the 250° F (394° K) stack temperature case. State points and stream flows are shown, where the enthalpy values are referenced to 32° F (273° K)



LEGEND Pressure/Temperature/Flow Rate/Enthalpy
PSIA/°F/Million Pounds Per Hour/BTU Per Pound
*Million Pounds Per Hour

Figure 3. - Modified Reference Plant Cycle Schematic (1250° F (394° K) Stack Gas Reheat Temperature) (Based on Fig. 2, Ref. 7).

water, for steam and water, and to an 80° F (300° K) zero reference for air, combustion gases, and solids.

The steam turbine is contained in four shells connected in tandem to a single 820 MW generator. The low pressure stages have parallel flows exhausting downward into a common condenser. The condenser coolant is water recirculated in a closed circuit to evaporative cooling towers. The regenerative feedwater heating cycle has four low-pressure feedwater heaters, a deaerating feedwater heater, and two high-pressure feedwater heaters. Part of the steam exhausted from the high-pressure turbine is used for feedwater heating, while the rest is returned to the boiler to be reheated to 1000° F (811° K). Part of the steam from the reheat turbine exhaust is used for driving the boiler feedpump. The exhausts from the three drive turbines are routed to the main condenser. All other pump drives are electric motor driven. The boiler feedpump and its drive are an integral part of the steam cycle and are fully accounted for in the heat balance for the steam turbine-generator.

The final feedwater temperature is 505° F (536° K) for 100 percent operation. All major components were specified for continuous performance capability at a flow margin of 5 percent above the intended plant operating flow. The steam cycle at the valves wide open (VWO) point would pass the intended flow with margin, and the designated 510° F (539° K) feed temperature would then exist. It is important in conventional steam systems that the operations be evaluated at the 100 percent operating point where performance is guaranteed, and not at the specification condition for design with margin.

The coal to be fired is dried by the primary airflow at the eight ball mill pulverizers. Between 15 and 20 percent of the total air is heated to 633° F (607° K) in the hottest part of the air preheater as primary air. This air serves to dry the coal, convey the pulverized coal to the burners, and react in the initial combustion process. The remainder of the air is preheated to 585° F (580° K) and delivered to the burners as secondary air.

The water circuitry in the steam generator provides water walls, radiant energy absorption surfaces, convection and radiant surfaces for superheating and reheating of steam, and an economizer to bring the flue gas to 740° F (666° K) as it leaves the boiler and enters the air preheater. Slag is removed from the boiler furnace beneath the firing zone, fly ash from a hopper just before the air preheater. These solids, representing 15 and 10 percent by weight (25 percent combined) of the total ash, respectively, are sluiced to the sludge pond. This leaves 75 percent (wt) of the total ash (as dust) remaining in the flow to the electrostatic precipitators. The electrostatic precipitators, with an efficiency of 99.7 percent, remove 99.7 percent (wt) of this remaining dust leaving only 0.225 percent (wt) of the total ash in the gas flow to the wet scrubbers. The collected fly ash is stored in dry silos for shipment off-site. Induced draft fans follow the electrostatic precipitators.

The wet gas scrubbers apply a spray of recirculated hot water that is rich in limestone in order to capture sulfur compounds. The remaining fly ash will be washed out of the flue gas also, as discussed in section A4.0. Following the main reactive spray there is a demisting spray that recirculates a makeup water and captured drift mixture. Carryover of the limestone slurry is avoided using this demisting spray in a properly designed mist eliminator. Acid mist carryover is also minimized using the mist eliminator as discussed in section A4.0.

A continual removal of sludge and a continual replenishment of limestone and water is required. The sludge is flushed to the sludge settling ponds in a stream comprising 10 percent undissolved solids. The return water from the pond is enriched with limestone.

The makeup water moves in a counterflow mode. It is first used in the mist eliminator recycle wash. The bleedoff replenishes the SO_2 absorber recycle liquids and eventually becomes part of the sludge and water mixture that accumulates in the settled portion of the sludge pond.

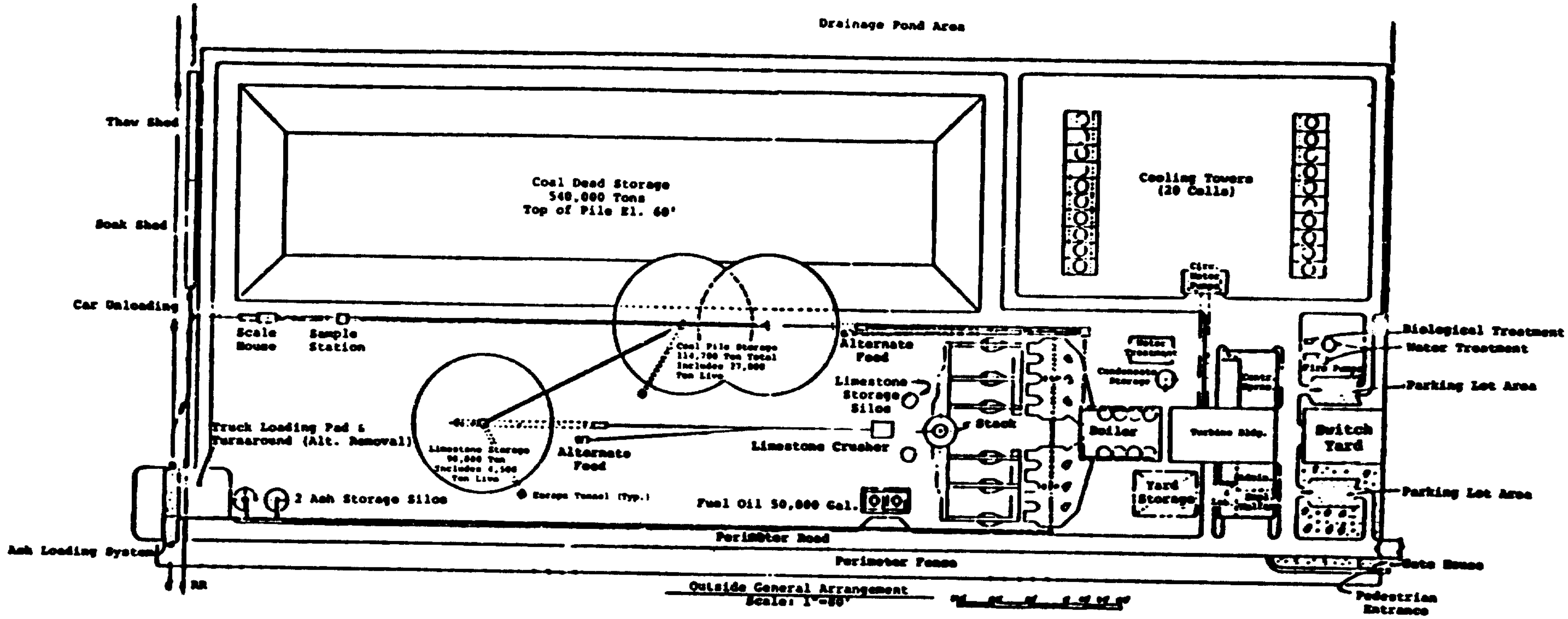
The flue gas at 125° F (325° K) leaves the wet scrubber saturated with water vapor and with many constituents at or near their dew point temperatures. Since direct in-line gas heaters cannot have suitable service lives when heating such a corrosive gas mixture, as discussed in section A3.0, an indirect method is employed. This is a large flow of air that has been separately heated and injected into the flue gas. Figure 2 shows that 14 Mlb/h (1764 kg/ \ of air heated to 334° F (441° K) blend with 8 Mlb/h (1008 kg/s) of flue gas to produce a 250° F (394° K) stack temperature. The stack air heaters use steam withdrawn from the steam cycle as their heating medium. The stack and flues are lined to withstand attack from the flue gases.

The major components of this system are conventinal and of proven reliability in utility service. The wet scrubber system utilizes equipment which requires maintenance and protection from the corrosive effects of limestone and cool flue gas. The subdivision of the scrubber into six parallel units, and the subdivision of critical pumping functions in the scrubber system, is designed to assure that at most one-sixth of the capacity would be down at any time.

4.2 Site Plan and General Arrangement

The plant site plan is based on receiving coal and limestone by rail and shipping fly ash off-site by rail. A 60 day pile of coal and limestone is provided. Solos to hold 15 days' accumulation of dry fly ash are provided adjacent to the rail terminal. A series of small ponds catch run-off water from the site and provide for treatment of all water returned to the North River.

Figures 3 and 4 show the site plan and general arrangement. The smaller overall layout at the bottom of figure 3 indicates the dominant size of one 3600- by 3600-foot (1097- by 1097-m) sludge pond. The upper detail of figure 3 shows that at the active site about half the area will be used for coal storage and cooling towers. The boiler house abuts the turbine building. The electrostatic precipitators are of substantial size in order to achieve 99.7 percent



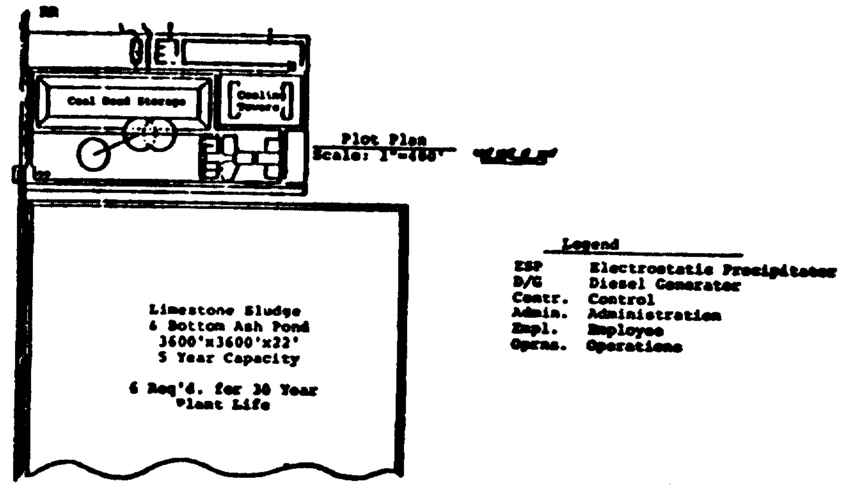


Figure 3. - Site Plan & General Arrangement (Based on Fig. 9, Ref. 7).

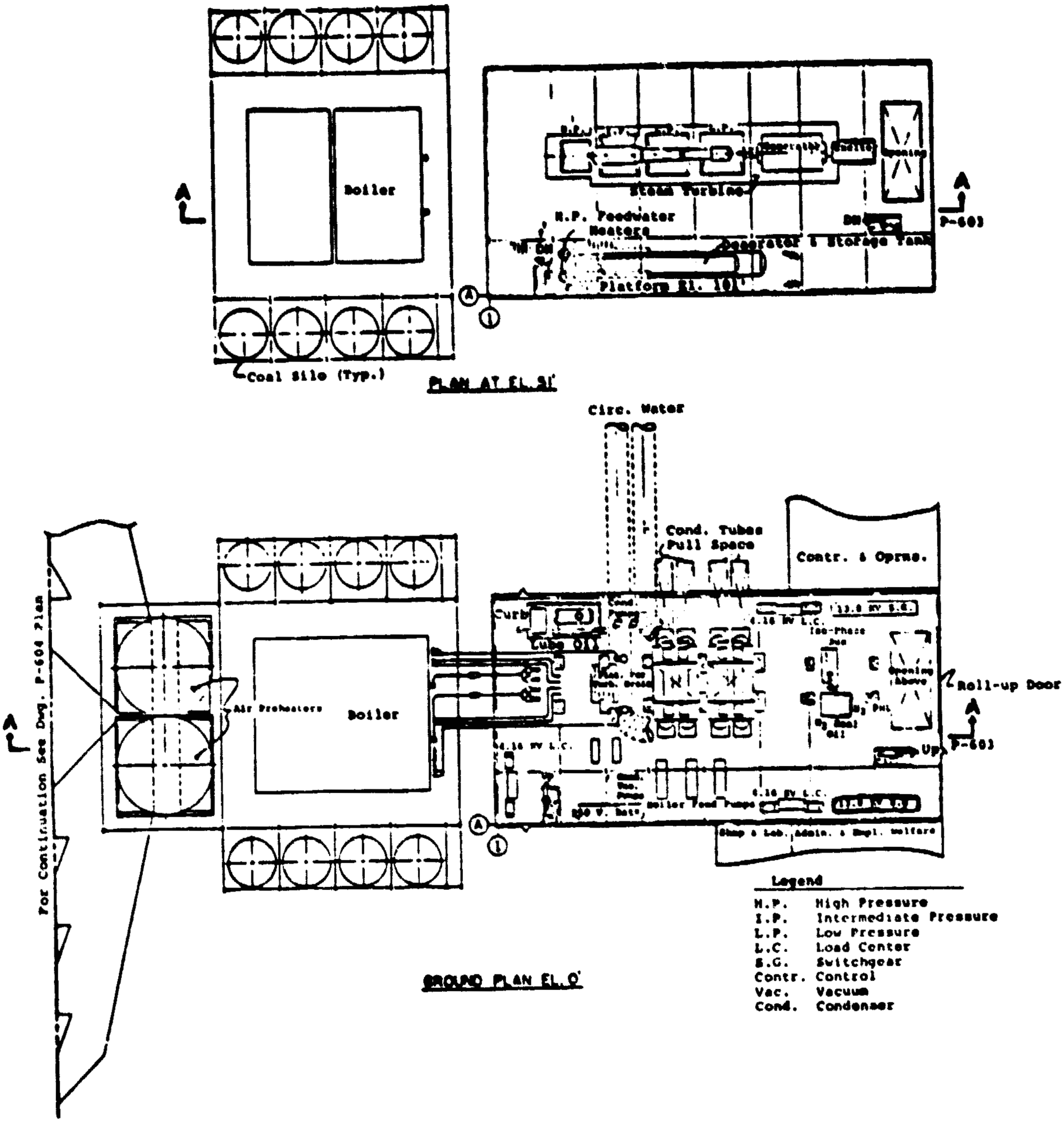


Figure 4. - Site Plan and General Arrangement (Concluded) (Based on Fig. 10, Ref. 7).

particulate removal. A single stack serves the entire plant. The estimated land area for the plant is 92 acres (372,311 m^2). The sludge ponds require an additional 1785 acres (7,223,640 m^2) in close proximity to the main plant.

The coal feed system provides transportation by belt conveyor from the line storage pile to the transfer tower. Tramp iron is removed and large size frozen coal is crushed to small size. Next, the coal is conveyed to the surge bin in the boiler house, where vibrating feeders and two conveyor belts feed eight coal silos disposed on opposite sides of the building. The filled silos guarantee eight hours of boiler output. Each silo feeds a single coal pulverizer by a gravimetric feed. Coal drying and conveyance to the burners is by hot primary air. For startup and warmup an oil system firing no. 2 fuel oil is provided, along with 100,000 gallons (379 m^3) of fuel storage in two tanks.

The plant general arrangement is presented in figure 4. The eight silos on either side of the boiler each hold an 8-hour coal supply and feed to one pulverizer. The air preheaters are significant features of the left side of the lower figure. The ground level of the turbine hall on the right side of the lower figure indicates the arrangement of the many support functions for the steam turbine cycle.

The general arrangement elevation view shown in figure 5 shows the boiler details and orientation relative to the turbine hall and the flue gas exhaust system. The arrangement provides for short steam lines and liberal access space for all apparatus. At the extreme left, the flue gas exits to the electrostatic precipitators and sulfur dioxide scrubbers.

The four electrostatic precipitators are sized to provide the low gas velocities essential to the capture of 99.7 percent of the flue gas fly ash. Each unit is nominally 54 feet (16.5 m) high, 93 feet (28.4 m) wide, and 44 feet (13.4 m) deep. The entry and exits are divided in two to retain normal flue connections. Each unit is services by one induced draft fan working in the cleaned gas leaving

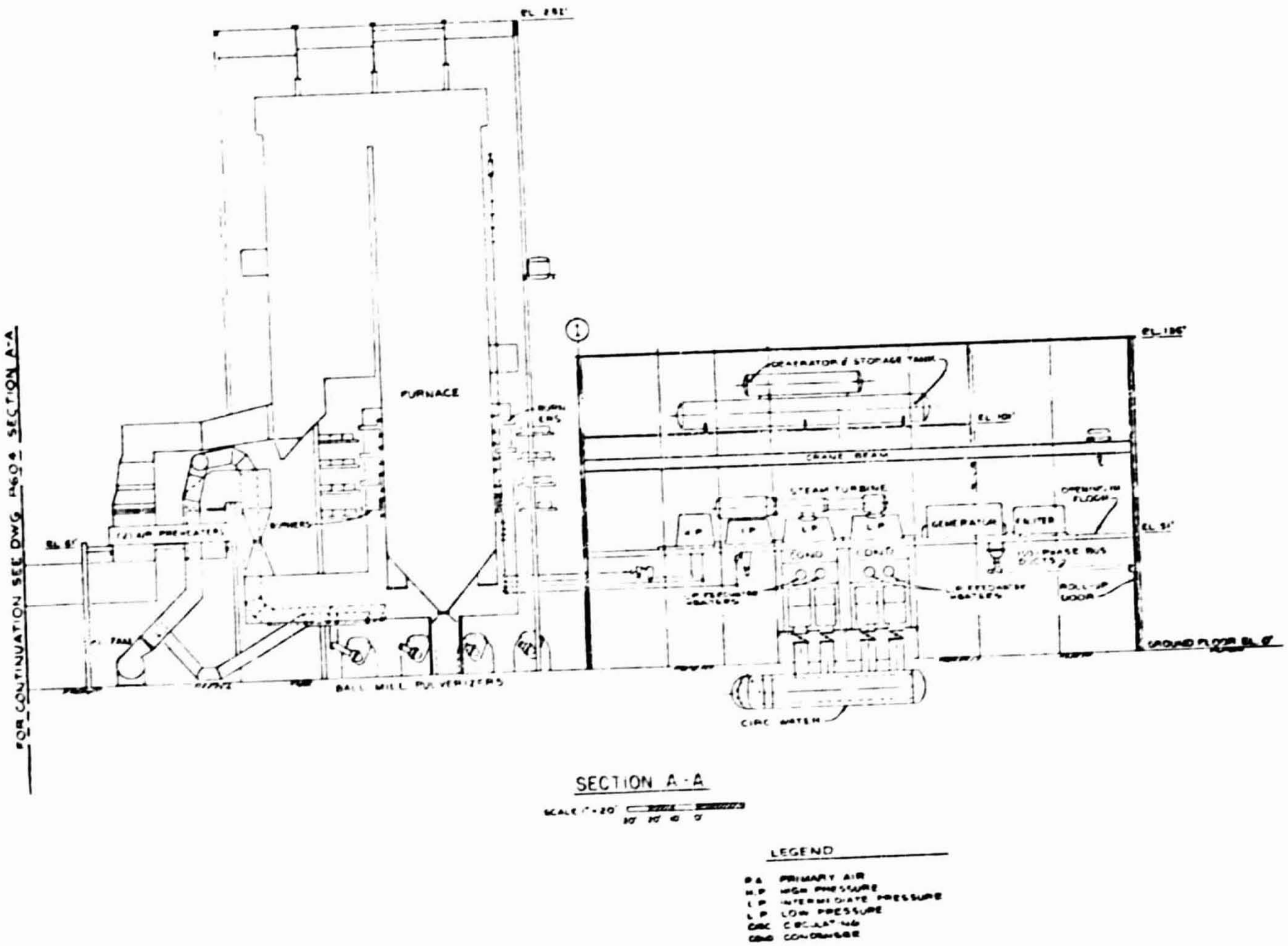


Figure 5. - Site Plan and General Arrangement - Elevation View (Based on Fig. 11, Ref. 7).

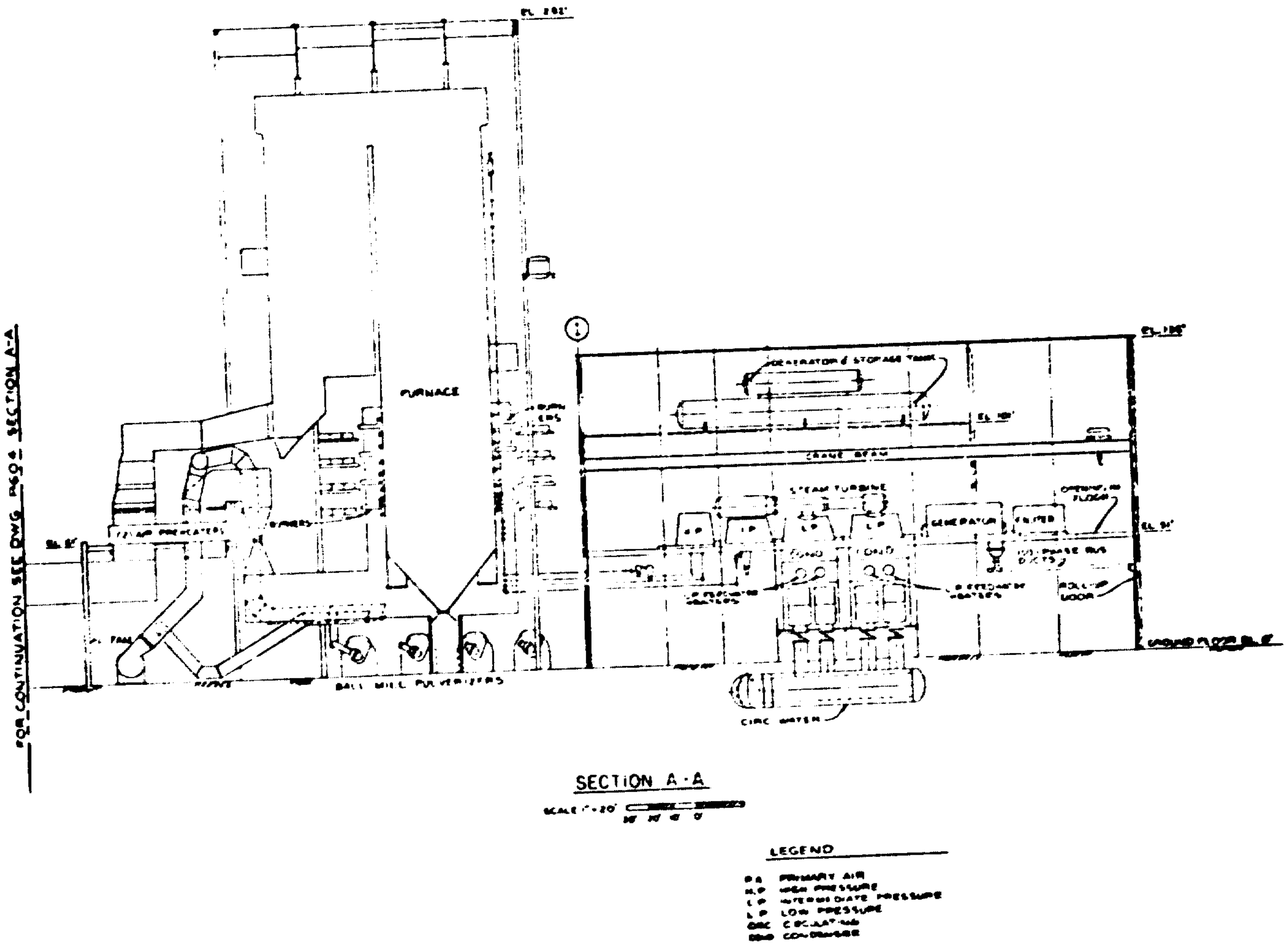


Figure 5. - Site Plan and General Arrangement - Elevation View
(Based on Fig. 11, Ref. 7).

the unit. The six wet gas scrubbers and reheaters then deliver the flue gas to a single 500-foot (152-m) stack.

4.3 Electrical One-Line Diagram

Figure 6 shows the plant electrical one-line diagram. The station service requirements at 3.8 KV may be seen to be supplied by two separate buses for increased reliability. An emergency diesel generator is also included to provide black-start capability should the plant be required to start up at a time when power from the external power network is unavailable.

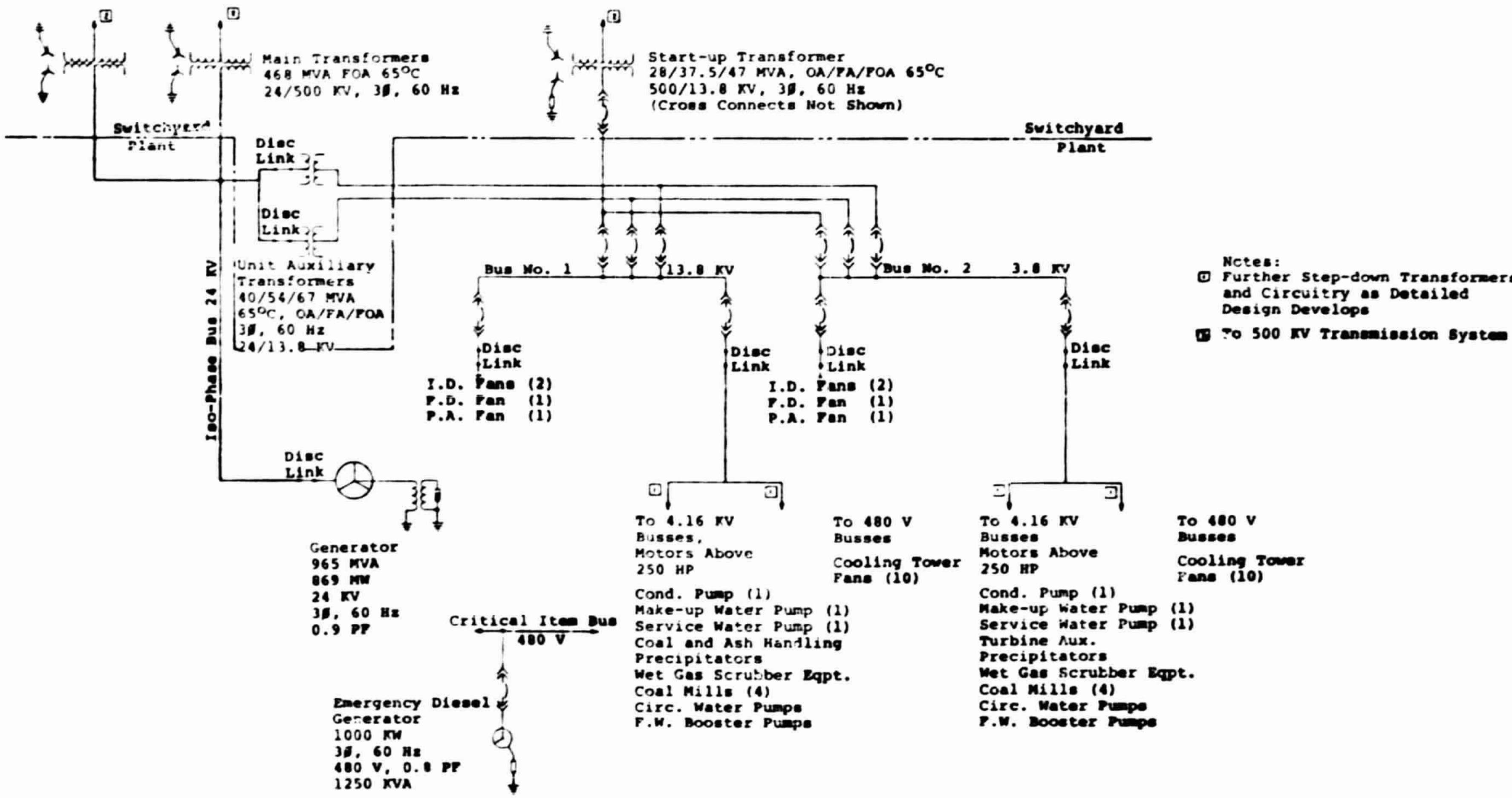


Figure 6. - Electrical One-Line Diagram (Based on Fig. 12, Ref. 7).

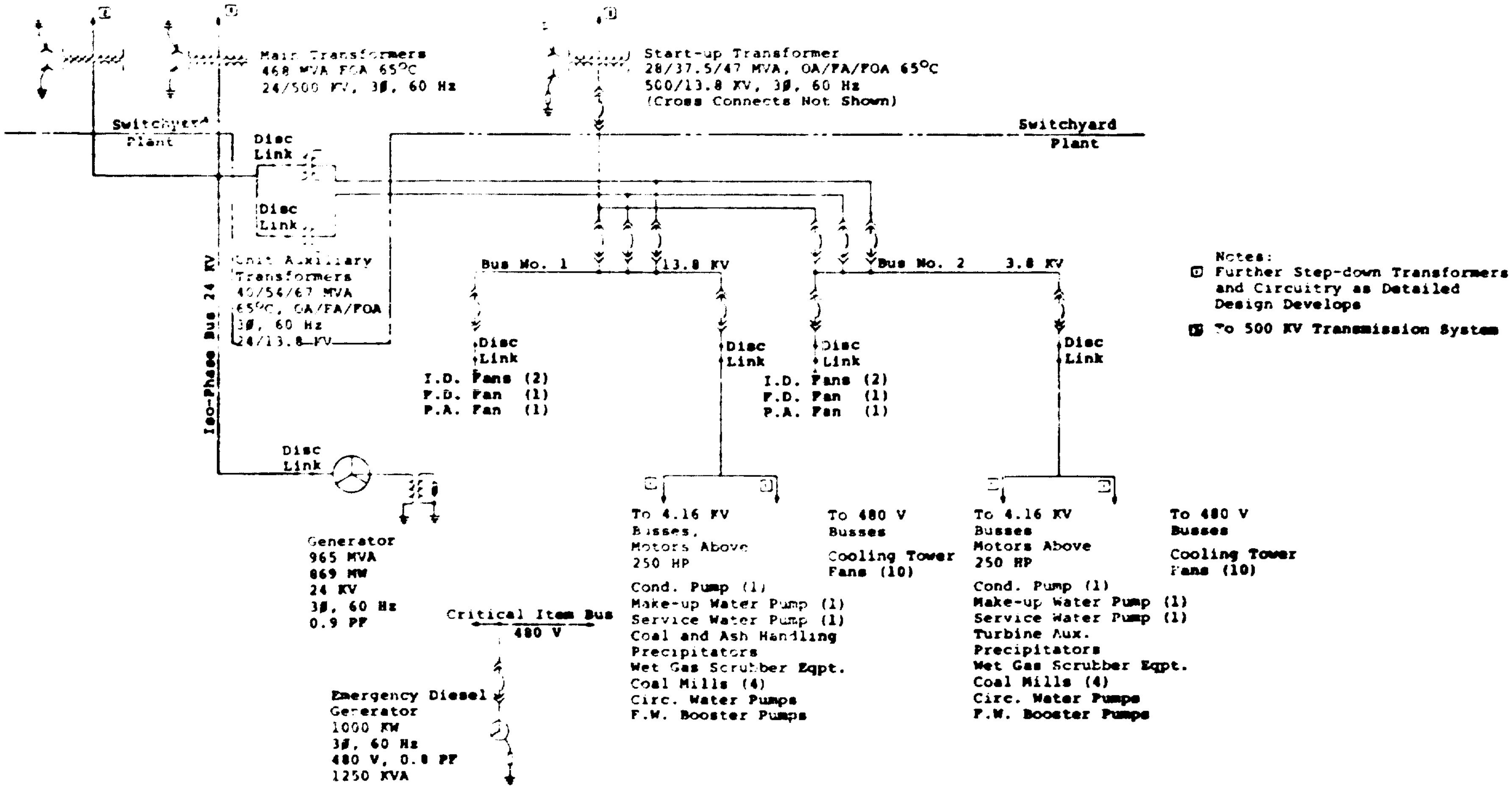


Figure 6. - Electrical One-Line Diagram (Based on Fig. 12. Ref. 7).

5.0 MAJOR PLANT COMPONENTS AND CHARACTERISTICS

This section briefly reviews the salient characteristics of the major plant components as originally presented in the ECAS study (Ref. 7) and adopted, with necessary changes, for use in the modified plant. Further details, not presented in this section, may be found by reference to the ECAS study (Ref. 7).

5.1 Steam Turbine-Generator

A heat balance for the steam cycle is presented in figure 7. It is identical to that for the ECAS reference plant. Operation at the 100 percent rated power conditions of 820 MW is shown for the 250° F (394° K) reheat temperature case. The 175° F (353° K) reheat case requires modification to account for the small extractions needed. The rating at the valves wide open (VWO) point is 860 MW. The seven feedwater heaters and the throttle and reheat conditions are typical of supercritical reheat units. The unusual feature is the 926,000 lb/h (117 kg/s) of extraction steam used for the stack gas heating service. The effect of the extraction on the steam turbine cycle is as if a separate condenser were located at the 134 psi (923,897 N/m^2) level. The reduction of steam flow to the low pressure stages reduces generator output and also the condenser and cooling-tower heat rejection load.

The steam turbine comprises four shells. The high-pressure turbine, the reheat turbine, and two double-flow low-pressure condensing turbines are arranged in tandem with the single generator. The last-stage turbine buckets are 33.5 inches (851 mm) long. These are the largest buckets applied to 3600 rpm turbines for fossil-fired service. The unit is specified as "TC4F33.5," indicating tandem compound, four exhaust flows, with 33.5-inch (851-m) last-stage buckets.

The heat to the steam cycle at 100 percent operating conditions is 6867.5 MBtu/hr (2.01 GJ/s). The heat input would be 8375.54 Btu/kWh (8.84 kJ/kWh) for generator output.

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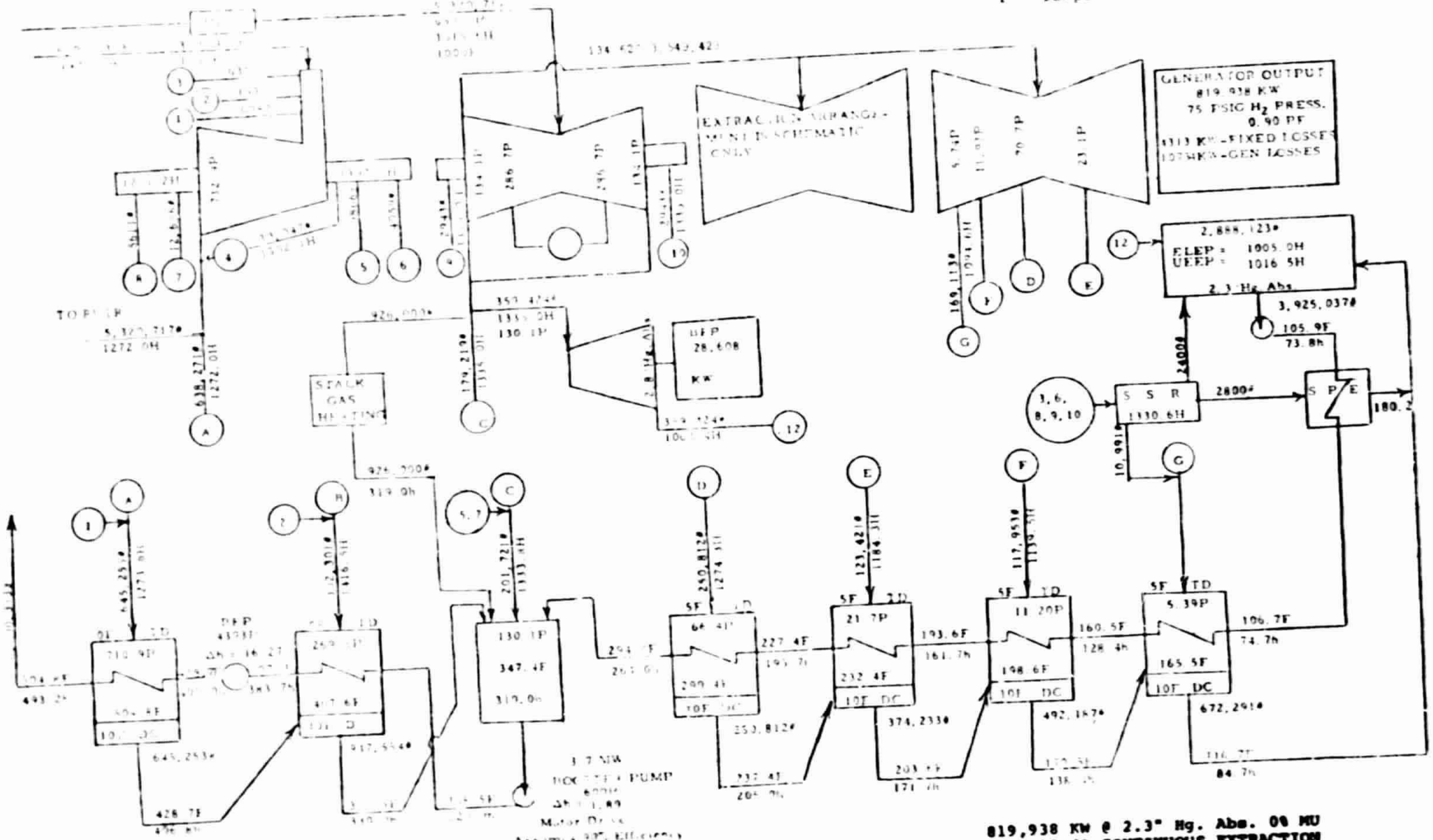
LEGEND: Calculations based on
1967 ASME Steam Tables
H, h - Enthalpy - Btu/Lb.
- Flow - Lb/Hr.
P - Pressure, Psia
F - Temperature, F degrees



VALVE BEST POINT = $\frac{6{,}000{,}313(1421.7 - 493.2) + 5{,}320{,}717(1515.6 - 1272.0)}{819{,}938 - 3697}$ = 8414 BTU/KW-H
NET HEAT RATE

GROSS HEAT RATE = 8375.54

819,938 KW @ 2.3" Hg. Abs. 0% MU
WITH 15.4% CONTINUOUS EXTRACTION
FOR STACK GAS HEATING
TC4F-33.5" LSB 3600 RPM
3500 PSIG 1000/1000°F
GEN: 992,200 KVA @ 75 PSIG H2 PRESS. & 0.90 PF(LIQ)

Figure 7. - Steam Cycle Heat Balance - 250° F (394° K) Stack Gas Reheat Temperature (Based on Fig. 5, Ref. 7).

5.2 Steam Generator

A general layout of the conventional supercritical once-through steam generator included in the plant is shown in figure 5. It is the same as that of the ECAS reference plant. Eight ball mill coal pulverizers are located at the base elevation. Low emission burners are arrayed about the radiant furnace section. The combustion gas flows upward over superheater sections, downward in parallel paths through the reheater and the primary superheater, and exits from the economizer.

In contrast to the ECAS reference plant design, a low-NO_x furnace configuration, such as that recently developed by one boiler manufacturer, is substituted for the "staged combustion" technique. The low-NO_x configuration includes a specially designed furnace chamber with directional low-emission burners to provide a diffuse, extended flame and uniform mixing throughout the combustion zone. This prevents the formation of high temperature regions where excess NO_x can be produced. It also permits stoichiometric firing. Since combustion stoichiometry was not addressed in the ECAS study (Ref. 7), it is assumed within the accuracy of this study, that the staged combustion technique referred to in the ECAS study permitted operation close enough to a stoichiometric mixture that any differences in air flow with that for stoichiometric firing could be neglected. The costs of the steam generator for the ECAS and modified plants were therefore estimated to be the same. Control of nitrogen oxides is discussed further in section A5.0.

5.3 Particulate Scrubber

The electrostatic precipitator is located downstream of the boiler air preheater as indicated in figures 2 and 3. It is of conventional design incorporating features that are characteristic of American units. For example, the plant includes weighted wires, maximum power density to minimize collection plate area, and frequency and intensity adjustable air driven rappers and vibrators.

5.4 Sulfur Dioxide Scrubber

A schematic diagram of the wet limestone sulfur dioxide scrubber system is shown in figure 8. The diagram is the same for both the 250° and 175° F (394° and 353° K) stack gas reheat temperature cases. The sulfur removal efficiency is 90 percent to meet the EPA June 1979 NSPS as discussed in section 3.1. A 60-day supply of limestone is stored on-site to provide continuity in case of any loss of supply.

The right half of figure 8 illustrates the portion of the scrubbing system that causes the limestone to react with the flue gas sulfur to form the solids that accumulate in the sludge ponds. Limestone is mixed with pond recycle water and transferred to a 16-hour slurry storage tank. The limestone slurry and pond recycle water are discharged to the SO_2 absorber effluent holding tanks where they are recycled to the SO_2 absorber.

The three-stage SO_2 absorber operates on flue gas that has been quenched from 300° F (422° K) and saturated with water vapor at 125° F (325° K) by presaturation sprays at each absorber unit gas inlet. The flue gas flows upward through the three absorber stages. The liquid-to-gas ratio maintains 110 to 120 percent of the calcium-to-sulfur stoichiometric ratio. The effluent wet gas is further washed in the mist eliminator sprays. These sprays receive all of the fresh water intended for makeup in the scrubber system. This final wash captures large droplets of drift or recycle wash liquids and is designed to minimize acid mist carryover.

The flue gas exiting the SO_2 scrubber at 125° F (325° K) and saturated with water vapor is highly corrosive and chemically active as noted in section 4.0. Normal heat exchangers that would reheat the flue gas to a stack temperature that would provide adequate buoyancy of the stack gas plume would not withstand the chemical attack of the flue gas as discussed in section A3.0. The necessary stack temperature, therefore, is achieved by steam-heating air in a separate heater and blending the heated air with the flue

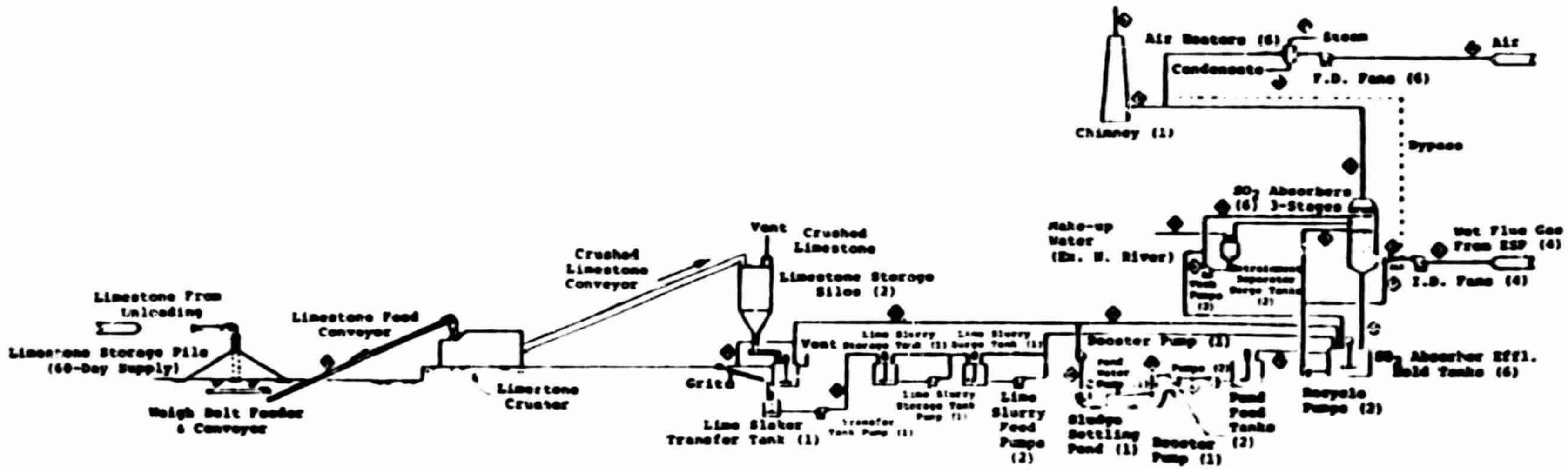


Figure 8. - Sulfur Dioxide Scrubber System Process Schematic (Based on Fig. 7, Ref. 7).

gas. Six low head fans and six heaters are provided for this purpose. Two alternatives of stack temperature were examined as previously noted: 250° F (394° K) and 175° F (353° K). Table IV lists the parameters of the blend air and its heat requirements for these alternatives at their 100 percent operating point. The blending method of gas heating makes the plant increasingly inefficient as the stack temperature is increased toward the available air temperature of 333° F (440° K), because of the increase in the steam extraction rate for the additional air heating associated with the higher stack gas reheat.

TABLE IV. - AIR HEATER PARAMETERS
FOR STACK GAS REHEAT SYSTEM
(Ref. 7, Table 4)

Parameter	Stack Gas Reheat Temperature, ° F (° K)	
	250 (394)	175 (353)
Heat Duty (10^6 Btu/hr)	971	217
Steam (° F) In/Out	620 /356	620 /356
Air (° F) In/Out	59 /333	59 /333
Air Velocity (ft/min)	900	900
Air Flow (10^6 lb/hr)	14.6	3.3
Pressure Drop (in. water)	1.5	1.0
Heat Transfer Rate (Btu/(hr)(sq ft)(° F))	5.5	10.4
Finned Surface (sq ft)	645,000	86,500

The sludge ponds are the remaining element of the wet scrubber system. Each pond measures 3600 feet (1097 m) by 3600 feet (1097 m) by 22 feet (6.7 m) deep. Six ponds would be expected to accommodate 30 years of plant operations. The accumulation rate of solids would equal the solids delivery rate of 150,000 lb/h (18.9 kg/s) of calcium sulfite and excess unreacted limestone.

5.5 Component Comparison: ECAS Reference Plant Versus Modified Reference Plant

Table V presents a comparison between the components of the ECAS and modified reference plants. Both the 250° and 175° F (394° and 353° K) stack gas reheat temperature cases are included. The table lists the design features, manhour installation times and balance-of-plant costs of all those items which differ from any one case to another. Each item is identified with the FERC Account Subdivision Number (as discussed in section '.4) in which it appears in the detailed capital cost estimates of section 7.2 and the ECAS report numbers (Ref. 7) which are used as designations in ECAS tables 15, 16, 27 and 28 (see Note 1 to the table).

All the component costs listed are in mid-1978 dollars. The costs for the ECAS reference plant have been updated from their mid-1975 values, as reported in the ECAS study (Ref. 7) and included in tables XXXII and XXXIII, to mid-1978, as discussed in section 7.0.

The table shows that there are a number of items which have design/cost differences between the 250° and 175° F (394° and 353° K) stack gas reheat temperature cases. These design/cost differences reflect, from the point of view of the 175° F (353° K) reheat case, the decreased quantity of steam diverted from the main turbine for reheat and consequent increased quantity of steam reaching the main condenser and condensate reaching the feedwater heaters. The table also shows that there are only three items which have design/cost differences between the ECAS and modified plants. The electrostatic precipitator and breeching (FERC Account Subdivision No. 312.71), sulfur dioxide scrubber (FERC Account Subdivision No. 312.81) and lime manufacturing system (on-site lime production; FERC Account Subdivision No. 312.83). The precipitators are increased in particulate removal efficiency from 99 to 99.7 percent, the wet sulfur dioxide scrubber is changed from lime to limestone utilization at 90 percent sulfur dioxide removal efficiency, and the lime manufacturing system is deleted entirely due to poor economics, as discussed in section A2.0.

TABLE V. - COMPARISON OF THE COMPONENTS AND ASSOCIATED MANHOUR (MH) INSTALLATION AND BALANCE OF PLANT (BOP) COSTS BETWEEN THE ECAS AND MODIFIED REFERENCE PLANTS (Mid-1978 Dollars)

EES Subdiv. Number	ECAS Report Ident. No(s) (1)	Title	ECAS Reference Plant (2) Stack Gas Reheat Temperature $^{\circ}$F ($^{\circ}$K) 250 (394)	ECAS Reference Plant (2) Stack Gas Reheat Temperature $^{\circ}$F ($^{\circ}$K) 175 (353)	Modified Reference Plant (2) Stack Gas Reheat Temperature, $^{\circ}$F ($^{\circ}$K) 250 (394)	Modified Reference Plant (2) Stack Gas Reheat Temperature, $^{\circ}$F ($^{\circ}$K) 175 (353)
312.42	6.7	Instrumentation and Controls (steam generator system)	Integrated boiler controls, boiler/turbine coordinating controls, main mechanical system control boards, sampling system including analyzers and sampling panel, stack emissions monitoring system and data acquisition system. 220,000 MH, $6,076,000 BOP	The same as the 250° F reheat case. 219,000 MH, $5,976,800 BOP	The same as the ECAS 250° F reheat case.	The same as the ECAS 175° F reheat case.
312.61	3.3, F-4	Main Condensate Pumps and Motors	Vertical centerline, 4250 gpm, 600 hp motor, 410 ft. TDH (2 reqd. @ $105,400 ea.) 5000 MH, $806,000 BOP (includes other pumps and drivers not listed elsewhere)	Vertical centerline, 5100 gpm, 750 hp motor, 410 ft. TDH (2 reqd. @ $117,800 ea.) 5000 MH, $830,000 BOP (includes other pumps and drivers not listed elsewhere)	The same as the ECAS 250° F reheat case.	The same as the ECAS 175° F reheat case.
	3.5, F-3	Feedwater Heaters	Flow (100 Percent) 10^6 lb/hr — Heat Transfer Area (sq. ft.) LP#1 4.05 14,330 LP#2 4.05 13,550 LP#3 4.05 13,720 LP#4 4.05 18,770 9000 MH, $3,794,400 BOP (includes miscellaneous heaters and exchangers; tanks and vessels; and intermediate pressure(1), high pressure (1) and deaerating feedwater heaters) (See Note 3.)	Flow (100 Percent) 10^6 lb/hr — Heat Transfer Area (sq. ft.) LP#1 4.75 17,170 LP#2 4.75 16,260 LP#3 4.75 16,600 LP#4 4.75 22,710 9000 MH, $3,918,400 BOP (includes miscellaneous heaters and exchangers; tanks and vessels; and intermediate pressure (1), high pressure (1) and deaerating feedwater heaters) (See Note 3.)	The same as the ECAS 250° F reheat case.	The same as the ECAS 175° F reheat case.

*See page 45 for explanation of footnotes.

TABLE V. - Continued

FERC Subdiv. Number	ECAS Report Ident. No(s) (1)	Title	ECAS Reference Plant (2) Stack Gas Reheat Temperature, °F (°K) 250 (394)	175 (353)	Modified Reference Plant (2) Stack Gas Reheat Temperature, °F (°K) 250 (394)	175 (353)
312.71	1.3, F-11, Table 14, Table 29	Precipitators and Breeching	54 ft. high x 92 ft. wide x 44 ft. long each, 1,262,000 lb, 1296 kVA, 99 percent particulate removal efficiency, 695,000 acfm @ 300° F, including support steel. 4 reqd. @ $1,[illegible],500 ea. 103,000 MH, $272,800 BOP	The same as the 250° F reheat case.	Nominally the same dimensions, weight and kVA rating as the ECAS 250° F reheat case, 99.7 percent particulate removal efficiency, 695,000 acfm @ 300° F, including support steel. 4 reqd. @ $2,500,000 ea. 103,000 MH, $272,800 BOP	The same as the modified 250° F reheat case.
312.72	3.6, F-15	Chimney	Concrete stack and liner; lights and marker painting; hoists and platforms; stack foundation 40 ft. I.D., 500 ft. high. 113,000 MH, $1,946,800 BOP	The same description as the 250° F reheat case except for the stack foundation which has a 27 ft. I.D. 86,000 MH, $1,537,600 BOP	The same as the ECAS 250° F reheat case.	The same as the ECAS 175° F reheat case.
312.73	3.14, F-15	Forced Draft Fans for Reheat Air	Operating: 545,000 cfm @ 80°F Total S.P. = 3.5 in. w.g. Test block: 654,000 cfm @ 105°F Total S.P. = 4.55 in. w.g. Motor: 650 hp 6 reqd. @ $248,000 ea. 13,000 MH (est.), $1,618,200 (est.) BOP	Operating: 123,000 cfm @ 80° F, Total S.P. = 3.5 in. w.g. Test block: 147,000 cfm @ 105° F Total S.P. = 4.55 in. w.g. Motor: 150hp 6 reqd. @ $105,400 ea. 3,000 MH (est.), $688,200 (est.) BOP	The same as the ECAS 250° F reheat case.	The same as the ECAS 175° F reheat case.
	3.14, F-13	Stack Gas Reheat Air Heaters	4.5 ft. high x 21.5 ft. wide x 37.5 ft. long each. 6 reqd. @ $347,200 ea. 14,000 MH (est.) $2,213,400 (est.) BOP	2.5 ft. high x 18.2 ft. wide x 10.7 ft. long each. 6 reqd. @ $62,000 ea. 4000 MH (est.) $427,800 (est.) BOP	The same as the ECAS 250° F reheat case.	The same as the ECAS 175° F reheat case.

*See page 45 for explanation of footnotes.

TABLE V. - Continued

SPC Subdiv. Number	ECAS Report Ident. No(s) (1)	Title	ECAS Reference Plant (2) Stack Gas Reheat Temperature, °F (°K) 250 (394)	ECAS Reference Plant (2) 175 (353)	Modified Reference Plant (2) Stack Gas Reheat Temperature, °F (°K) 250 (394)	Modified Reference Plant (2) 175 (353)
312.81	3.15, F-12	Wet SO_2 Scrubbers	Complete wet lime SO_2 scrubber vessels with presaturator and mist eliminator systems. 60 ft. high x 40 ft. wide x 18 ft. long, 316L stainless steel, neoprene lined, 3 stages, 450,000 acfm @ 312° F each. 6 reqd. @ $1,240,[illegible] ea. 8[illegible] MH, $[illegible],200 BOP	The same as the 250° F reheat case.	Complete wet limestone SO_2 scrubber vessels with presaturator and mist eliminator systems. Nominally 60 ft. high x 40 ft. wide x 18 ft. long, 316L stainless steel, neoprene lined, 3 stages, 450,000 acfm @ 312° F each. 6 reqd. @ $1,[illegible] ea. 86,000 MH, $10,560,000 BOP	The same as the modified 250° F reheat case.
	3.13	Scrubber Ductwork	Flue gas duct outboard of electrostatic precipitators, duct lining, duct insulation, dampers and expansion joints 207,000 MH, $4,054,800 BOP	The same description as the 250° F reheat case. 120,000 MH, $2,418,000 BOP	The same as the ECAS 250° F reheat case	The same as the ECAS 175° F reheat case.
	3.17	Scrubber system pumps	Slurry recycle (18 @ $49,600 ea.); mist eliminator wash (3 @ $31,000 ea.); slurry storage and transfer (4 @ $4,960 ea.); slurry feed (3 @ $6,200 ea.); pond feed tank (3 @ $12,400 ea.); pond feed booster (2 @ $18,600 ea.); pond water recycle and booster (4 @ $15,500 ea.) 10,000 MH, $1,339,200 BOP	The same as the 250° F reheat case.	Slurry recycle (18 @ $53,500 ea.); mist eliminator wash (3 @ $33,000 ea.); slurry storage and transfer (4 @ $5,500 ea.); slurry feed (3 @ $7,000 ea.); pond feed tank (4 @ $13,000 ea.); pond feed booster (2 @ $20,000 ea.); pond water recycle and booster (4 @ $16,500 ea.) 10,000 MH, $1,812,000 BOP	The same as the modified 250° F case.
	3.18	Scrubber system tanks	Tanks and agitators for absorber effluent hold, pond feed, entrainment separator surge, slurry surge, slurry storage and slurry transfer. 4,000 MH, $2,703,200 BOP	The same as the 250° F reheat case.	The same description as the ECAS 250° F reheat case. 4,000 MH, $3,360,000 BOP	The same as the modified 250° F reheat case.
	[illegible].2	Scrubber system large piping	[illegible] water, [illegible] slurry water, mist eliminator wash, absorber slurry effluent tank overflow, pond feed, pond recycle water, lime slurry, recycle slurry, air heater steam supply and air heater condensate return piping 53,000 MH, $3,261,200 BOP	The same description as the 250° F reheat case. 51,000 MH, $2,938,200 BOP	The same description as the ECAS 250° F reheat case except limestone slurry and recycle slurry piping replaces the lime slurry and recycle piping. 53,000 MH, $4,213,200 BOP	The same description as the modified 250° F reheat case. 51,000 MH, $3,920,000 BOP

*See page 45 for explanation of footnotes.

TABLE V. - Continued

[illegible]	[illegible] Report Ident. No(s) (1)	Title	ECAS Reference Plant (2)		Modified Reference Plant (2)	
			Stack Gas Reheat Temperature, °F (°K)		Stack Gas Reheat Temperature, °F (°K)	
			250 (394)	175 (353)	250 (394)	175 (353)
[illegible]	5.5	Foundations and Structural	Foundations earthwork and structures particular to scrubber equipment 180,000 MH, $4,538,400 BOP	The same as the 250° F reheat case	The same description as the ECAS 250° F reheat case 180,000 MH, $4,800,000 BOP	The same as the [illegible] reheat case.
.12 93	[illegible]	Lime Manufacturing System	Limestone calciner: 650 tons/day, nominal (880 tons/day, design), 12 ft. wide x 48 ft. long, travel-grate, 13 ft. I.D. x 180 ft. long rotary kiln with Niems - type cooler, coal conveyor, bucket elevator and storage bin, coal grinding/firing equipment, control panel/instrumentation, refractories, drives, induced draft fan, baghouse dust collector and ducting, kiln stack, lime conveyor bucket elevator, storage silos and lime slaker. traveling grate kiln [illegible] [illegible] MH, $4,[illegible] BOP	The same as the 250° F reheat case.	[illegible] from the plant design.	De[illegible]ted from the plant design.
[illegible]4.1	2.0 Table 14, Fig. 5, Table 24 Fig. 13	Steam Turbine and Auxiliaries	[illegible] guaranteed generator output, 15.4 percent continuous extraction (926,000 pph) for stack gas reheat. $33,020,000 Major Component 110,000 MH, $127,000 BOP (See Note 4)	369 MWe guaranteed generator output, 3.5 percent continuous extraction (213,426pph) for stack gas reheat. $33,972,500 Major Component 120,000 MH, $127,000 BOP (See Note 4)	The same as the ECAS 250° F reheat case.	The same as the ECAS [illegible] F reheat case.
[illegible]4.2	3.4, F-1	Condenser and Auxiliaries	Shells, tubes and air ejectors at 2.3 in. Hg (abs.), 3.31 x 10^5 sq. ft. of heat transfer area, 3.93 x 10^6 pph. 16,000 MH, $1,692,400 BOP	Shells, tubes and air ejectors at 2.3 in. Hg(abs.), 3.97 x 10^5 sq. ft. of heat transfer area 4.67 x 10^6 pph. 17,500 MH, $3,098,800 BOP	The same as the ECAS 250° F reheat case.	The same as the ECAS 175° F reheat case.

*See page 45 for explanation of footnotes.

TABLE V. - Concluded

FERC Subdiv. Number	ECAS Report Ident. No.(s) (1)	Title	ECAS Reference Plant (2)		Modified Reference Plant (2)	
			Stack Gas Reheat Temperature, ° F (° K)		Stack Gas Reheat Temperature, ° F (° K)	
			250 (394)	175 (353)	250 (394)	175 (353)
[illegible]	3.2, F-7	Circulating Water Pumps and Motors	82,[illegible] gpm, 2250 hp, 75 ft. TDH each. 3 reqd. @ $279,400 ea. 3,000 MH, $889,000 BOP	95,000 gpm, 2500 hp, 75 ft. TDH each. 3 reqd. @ $298,400 ea. 3000 MH, $952,500 BOP	The same as the ECAS 250° F reheat case.	The same as the ECAS 175° F reheat case.
	5.4	Circulating Water valves, Piping and Structures	See Subdivision 314.32 comparison	See Subdivision 314.32 comparison	See Subdivision 314.32 comparison.	See Subdivision 314.32 comparison.
314.32	3.11, F-8	(Cooling) Tower Structure	Mechanical draft towers with fans and motors (20 cells) 246,000 gpm 52,300 MH, $2,832,100 BOP	Mechanical draft towers with fans and motors (23 cells) 242,058 gpm (See Note 5). 60,000 MH, $3,276,600 BOP	The same as the ECAS 250° F reheat case.	The same as the ECAS 175° F reheat case.
	5.4, F-2	Tower Basin and Circulating Water System	Circulating water pump pads, riser and concrete envelope for pipe; cooling tower basin; circulating water pipe (I.D. = 114 in.) and valves; misc. steel and fire protection. 90,000 MH, $1,752,600 BOP	Circulating water pump pads, riser and concrete envelope for pipe; cooling tower basin; circulating water pipe (I.D. = 123 in.) and valves; misc. steel and fire protection. 105,000 MH, $2,133,600 BOP	The same as the ECAS 250° F reheat case.	The same as the ECAS 175° F reheat case.
314.43	6.5	(Miscellaneous Piping Systems) Hangers and miscellaneous labor operations	All hangers and supports, material handling, scaffolding and associated miscellaneous labor operations. 420,000 MH, $1,845,200 BOP	The same [illegible] as the 250° F reheat case. 419,000 MH, $1,803,400 BOP	The same as the ECAS 250° F reheat case.	The same as the ECAS 175° F reheat case.
	6.6	Pipe Insulation	53,000 MH, $838,200 BOP	62,000 MH, $812,800 BOP	The same as the ECAS 250° F reheat case.	The same as the ECAS 175° F reheat case.

*See page 45 for explanation of footnotes.

NOTES TO TABLE V

(1) Identification numbers in this column consisting of letters and numerals refer to tables 15 and 27 of the ECAS report (Ref. 7), reproduced in Appendix C, pages 178 to 180 (table 15) and 188 to 191 (table 27), for reference. Identification numbers in this column consisting of numerals only refer to tables 16 and 28 of the ECAS report, reproduced in Appendix C, pages 181 to 187 (table 16) and 192 to 198 (table 28), for reference. References to ECAS report tables are as indicated.

(2) All the costs of the equipment and balance-of-plant materials listed are as of mid-1978. Those listed in the ECAS Reference Plant columns are escalated from the mid-1975 values listed in tables XXXII and XXXIII, as discussed in section 7.0. (See also tables X to XIII).

(3) Only those feedwater heaters which have design changes are listed. The manhour (MH) and balance-of-plant (BOP) costs, however, are for all the heaters.

(4) Only those items which change are listed.

(5) This value is listed in the ECAS report (Ref. 7, table 27, Item F-8) and appears to be low. A value closer to 282,000 gpm would be more consistent with the addition of the three cooling tower cells and the increase of the circulating water pipe diameter from 114 in. to 123 in. indicated for the 175° F (353° K) stack gas reheat case.

Based on discussion with an emissions control equipment manufacturer, the estimated cost of each of the four electrostatic precipitator units with the increased efficiency required for the modified plant is \$2,500,000 compared to \$1,906,500 for the ECAS plant. The same precipitators and costs are included for both the 250° and 175° F (394° and 353° K) reheat cases, as shown, since approximately the same quantity of the flue gas is expected to be processed in each case. The direct labor manhours and balance-of-plant materials cost associated with the precipitator installations are also estimated to be the same for the two reheat temperatures and for both the ECAS and modified plants.

The estimated cost of each of the six wet limestone SO_2 scrubber units in the modified plant is \$1,500,000 compared to \$1,240,000 for the wet lime SO_2 scrubbers in the ECAS plant. The increased cost of the units in the modified plant results from the increased size and number of internals necessary to permit the greater quantities of limestone slurry to be sprayed into the flue gas flow to achieve the required 90 percent SO_2 removal. The same size units are provided for both the 250° and 175° F (394° and 353° K) reheat cases.

The SO_2 scrubber system pumps, tanks, large piping, and foundations and structures are also estimated to cost more for the modified plant than for the ECAS plant reflecting the greater quantities of limestone and limestone slurry required to be handled. Respectively, these balance-of-plant costs are estimated to be: \$1,812,000 compared to \$1,339,200 for the pumps, \$3,360,000 compared to \$2,703,200 for the tanks, \$4,213,200 compared to \$3,261,200 for the large piping (for the 250° F (394° K) reheat case), and \$4,800,000 compared to \$4,538,400 for the foundations and structures. A decrease in the cost of the large piping between the 250° and 175° F (394° and 353° K) reheat cases for both the ECAS and modified plants reflects the reduced reheat air heater steam supply and condensate return piping sizes required for reheat to 175° F (353° K). The decrease is seen to be \$3,261,200 to \$2,938,200 for the ECAS plant

and \$4,213,200 to \$3,920,000 for the modified plant. The cost of the scrubber ductwork is estimated to be about the same for both the modified and ECAS plants, since (as already noted) approximately the same quantity of flue gas is expected to be processed in each case. Since the physical sizes, weights and shapes of the SO_2 scrubber system components for both the ECAS and modified plants are expected to be nominally the same, no exception is taken to the values of their associated direct labor installation manhours, developed in the ECAS Study (Ref. 7), and the manhours are estimated to be the same as the ECAS values, as shown.

6.0 PLANT PERFORMANCE

Table VI summarizes the estimated output of the modified reference plant for the 250° and 175° F (394° and 353° K) stack gas reheat temperature cases. The auxiliary losses listed in the table are broken down in table VII. For the purposes of this study, the quantities listed are estimated to be the same as those of the ECAS reference plant (Ref. 7). The variations introduced in the ESP and scrubber losses, for example, are expected to be of secondary importance and not to affect any performance results of the ECAS reference plant. Selection of on-site limestone production, however, reduces the coal input rate to the modified plant by 2 percent and improves the overall plant efficiency by 0.5 and 0.6 percent for the 250° and 175° F (394° and 353° K) stack gas reheat cases, respectively.

TABLE VI. - ESTIMATED PLANT POWER OUTPUT*

	Stack Gas Reheat Temperature, ° F (° K)	
	250 (394)	175 (353)
Steam Cycle Output (MW)	819.9	868.6
Auxiliary Losses (MW)	72.7	73.1
Net Power Output (MW) 500 kV, 60 Hz, 3 phase	747.2	795.5

*Based on Ref. 7, Tables 10 and 26.

Table VIII summarizes the plant performance for the two reheat cases. As in the ECAS study (Ref. 7) the summary is broken into two parts; the first refers to the steam cycle, the second refers to the overall plant. The heat input to the steam cycle, 6867.4×10^6 Btu/hr, is the same for both the 250° and 175° F (394° and 353° K) reheat cases because the coal input and boiler efficiency were held

TABLE VII. - ESTIMATED PLANT AUXILIARY POWER LOSSES*

Item	Assumptions	No. of Units	Auxiliary Power, MW — Stack Gas Reheat Temperature, °F (°K) 250 (394)	175 (353)
Furnace				
FD Fans	19" ΔP, 0.82 eff	4	7.3	7.3
PA fans	42" ΔP, 0.82 eff	4	2.9	2.9
ID fans	23" ΔP, 0.78 eff	4	8.8	8.8
ESP	695,000 cfm, 300° F, 0.997 eff	4	5.2	5.2
Pulverizers		8	7.6	7.6
Subtotal			31.8	31.8
Turbine Auxiliary	0.33 percent of gross kW	1	2.8	2.9
Wet Scrubber			10.0	8.6
Major Pumps				
booster	600 psi, $6x10^6$ lb/hr, 75 percent x 90 percent	2	3.7	3.7
condensate	185 psi, $3.9x10^6$ lb/hr, 70 percent x 90 percent	2	1.0	1.0
circ. water	proportion to cooling heat duty	3	4.8	5.6
Subtotal			9.5	10.5
Water Intake	ECAS Estimate*	2	0.9	0.9
Solids Handling	Based on rates and lifts	1	3.0	3.0
"Hotel" Loads	ECAS estimate 1 percent of generation*	1	8.3	8.4
Cooling Tower Fans	Proportional to heat duty	20	2.3	2.7
Transformers	0.5 percent of gross generator	4	4.1	4.3
Total Auxiliary Power			72.7	73.1

*Based on Ref. 7, Tables II and 25.

TABLE VIII. - PLANT PERFORMANCE SUMMARY*

	Stack Gas Reheat Temperature, ° F (° K)	
	250 (394)	175 (353)
Steam Cycle		
Heat Input (10^6 Btu/hr)	6867.4	6867.4
Gross Power Output (MW)	819.9	868.6
Gross Heat Rate (Btu/kWh)	8376	7906
Thermodynamic Efficiency (percent)	40.7	43.2
Overall Plant		
Coal Heat Input Rate (10^6 Btu/hr)	7881	7881
Net Power Output (MW)	747.2	795.5
Net Heat Rate (Btu/kWh)	10,547	9907
Efficiency (percent)	32.3	34.4

*Based on Ref. 7, Tables 21 and 31 and Figures 2 and 5.

at constant values. The gross power output, however, is significantly lower in the 250° F (394° K) case, due to the extraction of 926,000 lb/hr of steam at the crossover point for the flue gas reheat air heaters in the 250° F (394° K) case compared to 213,426 lb/hr in the 175° F (353° K) case. As a result, the steam cycle gross heat rate, which is the ratio of the steam cycle heat input to the steam cycle gross power output is significantly higher for the 250° F (394° K) case than the 175° F (353° K) case. Specifically, it requires 8376 Btu of input thermal energy to produce each kilowatt hour of electrical energy in the 250° F (394° K) reheat case compared to 7906 Btu of input thermal energy to produce each kilowatt hour of electrical energy in the 175° F (353° K) reheat case. These requirements can be alternatively expressed as thermodynamic efficiencies of 40.7 and 43.7 percent, respectively, for the two cases relative to an ideal plant which requires 3412 Btu of thermal energy to produce each kilowatt hour of electrical energy.

Total heat input to the modified plant is held at 7881×10^{6} Btu/hr based on the HHV of the coal. This coal input rate is identical to the fuel input rate used in the ECAS reference plants when the coal for the on-site lime production is excluded. The boiler efficiency of 87.13 percent is used for both cases as in the ECAS. Noting that the net plant power output is 747.2 MW for the 250° F (394° K) reheat case and 795.5 MW for the 175° F (353° K) reheat case, the net plant heat rates are 10,547 Btu/kWh and 9907 Btu/kWh, respectively, for the two cases. These, alternatively, represent overall plant efficiencies of 32.3 and 34.4 percent. It is of interest that both of these efficiencies are slightly higher than the corresponding values calculated for the ECAS reference plant (31.8 and 33.8 percent, Ref. 7, Tables 21 and 31).

7.0 DETAILED PLANT CAPITAL COST ESTIMATES

This section presents the detailed capital cost estimates, as of mid-1978, for the ECAS and modified reference plant conventional furnace coal-fired power plants with wet SO_2 scrubber and 250° and 175° F (394° and 353° K) stack gas reheat temperatures. Specifically, the estimates are for the

1. ECAS reference plant - 250° F (394° K) reheat (table X)
2. ECAS reference plant - 175° F (353° K) reheat (table XI)
3. Modified reference plant - 250° F (394° K) reheat (table XII)
4. Modified reference plant - 175° F (353° K) reheat (table XIII)

The format employed was specified by NASA, with a few minor variations, and is discussed in section 3.4. The numbering and titles of the major cost accounts (i.e., account numbers 310., 311., 312., 314., 315., 316.) conform to those specified in the uniform systems of Federal Energy Regulatory Commission (FERC) accounts (Ref. 8) (formally called Federal Power Commission (FPC) accounts), and the subdivision titles generally conform to those employed in the "(MHD) Engineering Test Facility (ETF) Design Report" (Ref. 5). The following section provides a pictorial guide to the components which are included in the FERC accounts.

7.1 Cost Accounts Associated With the Major Plant Components

Figure 9 (adopted from Ref. 7, Fig. 2) presents a schematic process flow diagram for the reference conventional furnace coal-fired power plant with wet SO_2 scrubber. The diagram is based on the ECAS reference plant which utilizes a limestone calciner. Indicated in the figure are the numbers of the respective FERC accounts or subdivisions in which each of the components or systems illustrated is included. For ease of reference, the corresponding titles of the accounts and subdivisions are listed in table IX.

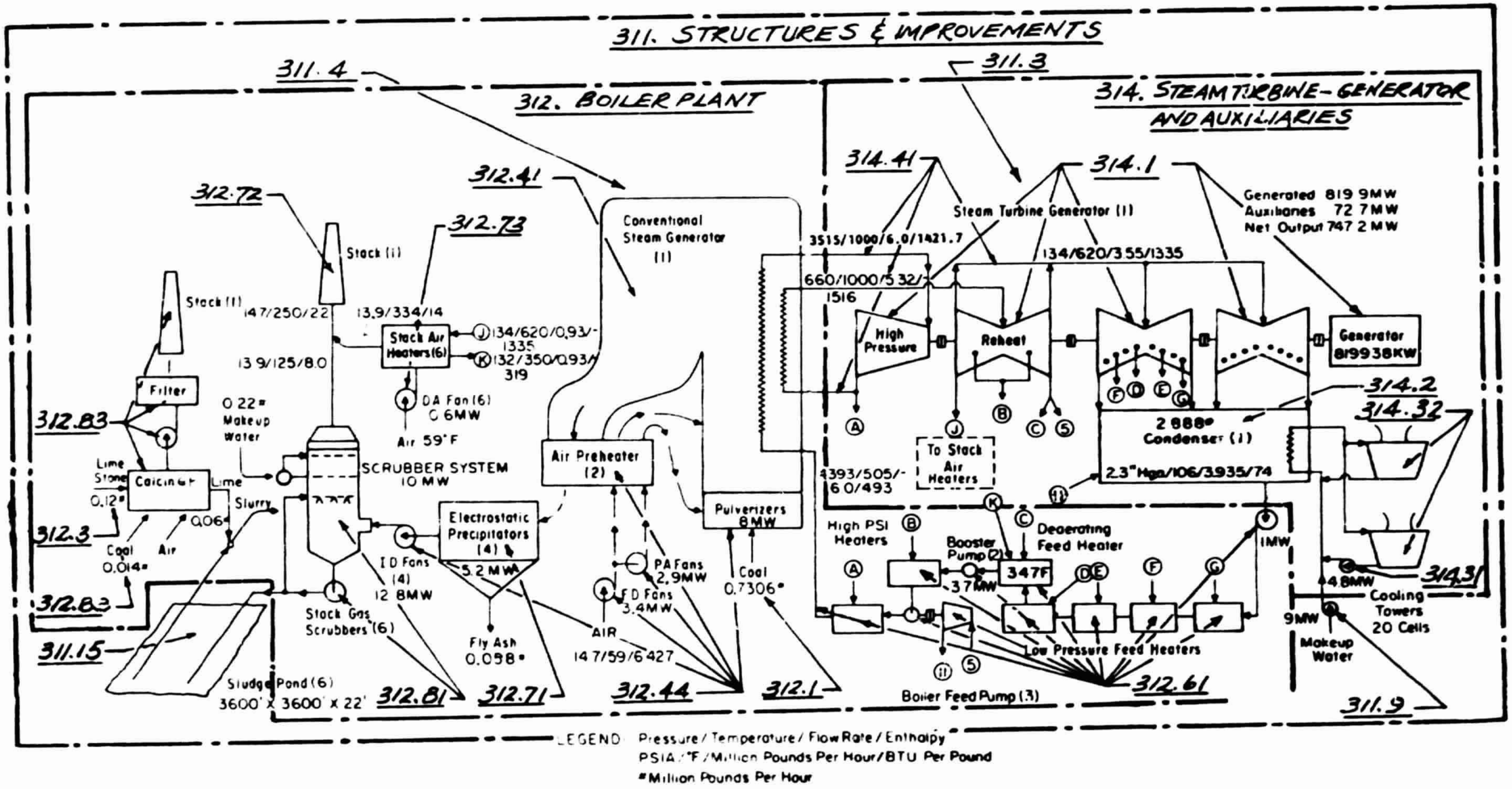


Figure 9. - Process Schematic of the Reference Conventional Furnace Coal-Fired Power Plant With Wet SO_2 Scrubber (Adopted From Ref. 7, Fig. 2) Indicating the FERC Accounts and Subdivisions in Which the Components and Systems Illustrated Are Included (See table IX for account titles).

TABLE IX. - TITLES OF THE FERC ACCOUNTS INDICATED ON THE PROCESS SCHEMATIC OF FIGURE 9

FERC Acct. No.	Account Title
311.	STRUCTURES & IMPROVEMENTS
311.15	Water Treatment Ponds
311.3	Main (Turbine-Generator) Building
311.4	Steam Generator Building
311.9	On-Site Waste Treatment (Including Water Treatment) Building
312.	BOILER PLANT
312.1	Coal Handling
312.3	Limestone Handling
312.41	Steam Generator (Equipment)
312.44	(Steam Generator) Auxiliaries
312.61	Condensate and Feedwater System
312.71	Precipitators and Breeching
312.72	Chimney
312.73	Stack Gas Reheat System
312.81	Flue Gas Desulfurization Equipment
312.83	Lime Manufacturing System
314.	STEAM TURBINE-GENERATOR AND AUXILIARIES
314.1	Steam Turbine and Auxiliaries
314.2	Condenser and Auxiliaries
314.31	(Circulating Water System) Pumps, Valves, Piping and Structures
314.32	Cooling Towers
314.41	Main Steam (Piping Systems)

To revise the schematic to represent the modified reference plant, the only significant change necessary is to replace the lime manufacturing system (calciner, calciner coal supply, calciner exhaust gas cleanup and lime transfer system) with a limestone preparation system (limestone pulverizer and slurry preparation tank). The limestone preparation system will also replace the lime manufacturing system in FERC Account Subdivision 312.83. The material flows indicated in figure 9, of course, will require alteration too, but this will not affect the FERC account in which the equipment is listed.

7.2 Detailed Capital Cost Estimate Tables

Tables X, XI, XII and XIII present the detailed capital cost estimates for the four reference plant configurations considered in this study. Each of the estimates is based on the original ECAS cost estimate details developed as part of the ECAS study (Ref. 7), which are included in Appendix C, for reference. To provide the means to correlate the estimates in this section with those in Appendix C, each of the estimate items in this section is identified (in the second column of each account subdivision) with the number(s) of the associated item(s) in the ECAS estimates.

Since the ECAS estimates were not in the format required for this study, they were recast appropriately. For reference, the recast estimates are included in Appendix E, since they are in mid-1975 dollars rather than mid-1978 dollars. For inclusion in this section, the estimates were updated to reflect costs as of mid-1978. This was accomplished by applying separate escalation factors to each of the FERC accounts. These account specific factors were calculated from the Handy-Whitman Index of Public Utility Construction Costs (Ref. 9), as discussed in Appendix B and listed in table XXV, and were applied appropriately to escalate the major component, balance-of-plant materials, installation and indirect costs of each account. A 20 percent contingency factor, as employed in the ECAS study, was applied

TABLE X. - ECAS REFERENCE CONVENTIONAL FURNACE COAL-FIRED POWER PLANT WITH WET SO_2 SCRUBBER CAPITAL COST ESTIMATE DETAILS AS OF MID-1978 (250° F Stack Gas Reheat Temperature (1)) (Mid-1978 Dollars)

FERC Account Number	ECAS Report Ident. No(s). (2)	Account/Subdivision		Material Costs		Installation Cost (3)	Indirect Cost (4)	Contingency Allowance (5)	Total Cost
		Title	Description/Specification	Major (3) Component	Balance (3) of Plant				
310.	-	LAND AND LAND RIGHTS	- - -			Not Included in Study			
311.	-	STRUCTURES AND IMPROVEMENTS (6)	Total Account 311.	-	[illegible]3,155,560	12,374,[illegible]	11,377,956	7,327,043	43,64[illegible]
311.1	7.0	Improvements to Site	Total Subdivision 311.1	-	1,647,200	3,530,170	3,178,656	1,671,205	10,027,231
311.11	7.1	Site Preparation and Improvements	Soil testing, clearing and grubbing, rough grading, finish grading, landscaping	-	11,600	1,185,810	1,067,734	453,029	2,718,172
311.12	7.2	Site Utilities	Storm and sanitary sewers, non-process service water	-	58,000	68,150	61,354	37,503	225,017
311.13	7.3	Roads and Railroads	Railroad spur, roads, walks and parking areas	-	858,400	368,010	331,366	311,555	1,869,331
311.14	7.4	Yard and Plant Fire Protection, Fences and Gates	- - -	-	696,000	708,760	638,186	408,589	2,451,535
311.15	7.5	Water Treatment Ponds	Earthwork, pond lining, off-site pipeline	-	23,200	1,199,440	1,080,006	460,529	2,763,176
311.3	-	Main (Turbine-Generator) Building	Total Subdivision 311.3	-	2,822,280	2,234,160	2,011,440	1,413,576	8,481,456
311.31	5.1,5.3	-	Excavation, substructure, dewatering and piling, including excavation and substructure for transmission plant switchyard	-	-	-	-	-	-
311.32	5.2	-	Building structure and services	-	-	-	-	-	-
311.4	-	Steam Generator Building	Total Subdivision 311.4	-	6,927,520	5,483,320	4,936,960	3,469,560	20,817,360
311.41	5.1,5.3	-	Excavation, substructure, dewatering and piling	-	-	-	-	-	-
311.42	5.2	-	Enclosure structure and services	-	-	-	-	-	-

*See page 70 for explanation of footnotes

TABLE X. - (Continued)

FEPC Account Number	ECAS Report Ident. No(s).(2)	Account/Subdivision		Material Costs		Installation Cost (3)	Indirect Cost (4)	Contingency Allowance(5)	Total Cost
		Title	Description/Specification	Major (3) Component	Balance (3) of Plant				
311.6	-	Maintenance, Service, Warehouse and Office Building (Service Building)	Total Subdivision 311.6	-	962,800	762,120	685,560	482,096	2,892,576
311.61	5.1,5.3	-	Excavation, substructure, dewatering and piling	-	-	-	-	-	-
311.62	"	-	Building Structure and services	-	-	-	-	-	-
311.7	5.1,5.3	Other Buildings	Total Subdivision 311.7 Excavation and structure for makeup water intake	-	256,360	203,000	183,280	128,528	771,168
311.8	3.7	Cranes and Hoists	Total Subdivision 311.8 Crane and accessories in turbine hall	-	475,600	40,890	36,818	110,662	663,970
311.9	5.1,5.2	On-site Waste Treatment (Including Water Treatment) Building	Total Subdivision 311.9 Excavation, substructure building structure and services; lime. alum, ion exchange resin, acid, caustic and chlorine storage tanks; reagent metering and feeding pumps; mixers; clarifiers	-	63,800	51,040	45,240	32,016	192,096

*See page 70 for explanation of footnotes

TABLE X. - (Continued)

FERC Account Number	ECAS Report Ident. No(s).(2)	Account/Subdivision Title	Account/Subdivision Description/Specification	Material Costs: Major (3) Component	Material Costs: Balance (3) of Plant	Installation Cost (3)	Indirect Cost (4)	Contingency Allowance (5)	Total Cost
312.	-	BOILER PLANT (3)	Total Account 312.	56,891,200	75,167,760	34,651,180	31,202,021	39,582,432	237,494,593
312.1	3.8, 5.1, 5.3	Coal Handling	Total Subdivision 312.1	-	8,914,360	2,407,770	2,169,201	2,698,272	16,189,603
			Coal, limestone and ash handling excavations, foundations pits & tunnels. Also, railcar dumping equipment, dust collectors, primary & secondary crushing equipment, belt scale, sampling station, magnetic cleaners, mobile equipment, coal silos, reclaiming feeders, and the following conveyors to coal pile and coal silos:						
312.11	-	Unloading and Yard Storage	- - -	-	-	-	-	-	-
	C-1	Coal Conveyor belt	60 in. wide, 340 ft. long, 3000 tph	-	-	-	-	-	-
	C-2	Coal Conveyor belt	60 in. wide, 760 ft. long, 3000 tph	-	-	-	-	-	-
	C-3	Coal Conveyor belt	60 in. wide, 190 ft. long, 3000 tph	-	-	-	-	-	-
312.12	-	Reclaim and Delivery	- - -	-	-	-	-	-	-
	C-4	Coal Conveyor belt	42 in. wide, 980 ft. long, 500 tph	-	-	-	-	-	-
	C-5	Coal Conveyor belt	42 in. wide, 540 ft. long, 500 tph	-	-	-	-	-	-
	C-6	Coal Conveyor belt	42 in. wide, 170 ft. long, 500 tph	-	-	-	-	-	-
	C-7	Coal Conveyor belt	42 in. wide, 110 ft. long, 500 tph	-	-	-	-	-	-
	C-8	Coal Conveyor belt (2 reqd.)	30 in. wide, 160 ft. long, 300 tph	-	-	-	-	-	-

*See page 70 for explanation of footnotes

TABLE X. - (Continued)

FERC Account Number	ECAS Report Ident. No(s). (2)	Account/Subdivision		Material Costs		Installation Cost (3)	Indirect Cost (4)	Contingency Allowance (5)	Total Cost
		Title	Description/Specification	Major (3) Component	Balance (3) of Plant				
312.2	3.10	Slag and Ash Handling	Total Account 312.2	-	4,439,200	888,770	800,271	1,225,648	7,353,889
			Bottom ash system, fly ash handling system for precipitators and air preheater, ash conveyors, railcar loading equipment, ash hoppers, sluice pumps and drives, piping, clinker grinder, pressure blowers, valves and piping, and the following storage silos and associated equipment:						
312.21	C-16	Fly ash storage silos (2 reqd.)	Feeders, unloaders and foundations, silos: total volume 833,184 cu. ft., 85 ft. high, 80 ft. dia.	-	-	-	-	-	-
312.3	3.9	Limestone Handling	Total Subdivision 312.3	-	1,550,000	320,540	288,622	431,832	2,590,995
			Magnetic cleaners, reclaiming feeders, belt scale, and the following conveyors to limestone pile and calciner:						
312.31	-	Conveyors		-	-	-	-	-	-
	C-9	Limestone Conveyor belt	60 in. wide, 500 ft. long, 3000 tph	-	-	-	-	-	-
	C-10	Limestone Conveyor belt	24 in. wide, 630 ft. long, 65 tph	-	-	-	-	-	-
	C-11	Limestone Conveyor belt	24 in. wide, 420 ft. long, 65 tph	-	-	-	-	-	-
	C-12	Limestone bucket Conveyor	24 in. wide, 120 ft. long, 100 tph	-	-	-	-	-	-

*See page 70 for explanation of footnotes

TABLE X. - (Continued)

FERC Account Number	ECAS Report Ident. No(s). (2)	Account/Subdivision		Material Costs		Installation Cost (3)	Indirect Cost (4)	Contingency Allowance (5)	Total Cost
		Title	Description/Specification	Major Component (3)	Balance of Plant (3)				
312.4	-	Steam Generator Equipment	Total Subdivision 312.4	49,265,200	16,591,200	18,314,490	16,490,834	20,132,345	120,794,370
312.41	1.1, Table 14	Steam Generator	Heat transfer surface and pressure parts; buckstays, braces and hangers; fuel-burning equipment, accessories, soot and ash equipment; control systems, brick-work, refractory and insulation; support steel & misc. materials; primary air fans & feedwater piping	49,265,200	8,432,000	12,238,600	11,020,128	16,191,226	97,147,354
312.42	6.7	Instrumentation and Controls	Integrated boiler controls boiler/turbine coordinating controls, main mech. system control boards, sampling system includ. analyzers and sampling panel, stack emissions monitoring system, and data acquisition system	-	6,076,000	3,205,400	2,886,224	2,433,525	14,601,149
312.43	1.2	Auxiliaries	Air preheater; flues and ducts to pre-cipitators; insulation for flues and ducts; pulverizers, feeders and hoppers; and the following fans:	-	2,083,200	2,870,290	2,584,482	1,057,594	9,065,567
	F-9	Forced draft fans (2 reqd. @ $483,600 ea.)	Operating: 971,000 cfm @ 80° F, S.P. outlet = 19 in. w.g. Test block: 1,165,000 cfm @ 105° F, S.P. outlet = 24.7 in. w.g. Motor: 6,500 hp	-	-	-	-	-	-

*See page 70 for explanation of footnotes

TABLE X. - (Continued)

FERC Account Number	EJAS Report Ident. No(s). (2)	Account/Subdivision: Title	Account/Subdivision: Description/Specification	Material Costs: Major Component (3)	Material Costs: Balance of Plant (3)	Installation Cost (3)	Indirect Cost (4)	Contingency Allowance (5)	Total Cost
	F-10	Primary air fans (2 reqd.)	Operating: 161,750 cfm @ 960 F, S.P. inlet=19 in. w.g., S.P. outlet = 42 in. w.g. Test Block: 194,000 cfm @ 1210 F, S.P. inlet=19 in. w.g., S.P. outlet=54.6 in. w.g. Motor: 2,250 hp	Included in Subdivision .12.42					
	F-14	Induced draft fans (4 reqd. @ $272,800 ea.)	Operating: 660,000 cfm @ 300° F, Total S.P. = 23 in. w.g. Test block: 800,000 cfm @ 325° F, Total S.P.=30 in. w.g. Motor: 5,000 hp	-	-	-	-	-	-
312.5	-	Auxiliary Boiler System	Optional (not included)	-	-	-	-	-	-
312.6	-	Other Boiler Plant Systems	Total Subdivision 312.6	-	8,593,400	349,680	314,861	1,851,588	11,109,529
312.61	-	Condensate and Feedwater System	Total Subdivision 312.61	-	8,593,400	349,680	314,861	1,851,588	11,109,529
	3.3, F-4	Main condensate pumps & motors (2 reqd @ $105,400 ea.)	Vertical centerline, 4250 gpm, 600 hp motor, 410 ft. TDH (Other pumps and drivers not listed elsewhere)	-	806,000	72,850	65,596	188,889	1,133,335
	3.1, F-5 (7)	Feedwater booster pumps and motors (2 reqd. @ $155,000 ea.)	7,300 gpm, 3850hp, 1510 ft. TDH	-	341,500	29,140	26,238	79,375	476,254
	3.1, F-6 (7)	Main boiler feed pumps and turbine drives ([illegible] reqd. @ $1,165,[illegible] ea.)	4900 gpm, 12,600 hp, 8300 ft. TDH	-	3,651,500	116,560	104,954	774,603	4,647,617
	F-2	Boiler feedwater piping	- - -	Included in Subdivision 314.41					
	3.5, F-3	Feedwater heaters	Miscellaneous heaters and exchangers; tanks and vessels; and the following low pressure (4), intermediate pressure (1) and deaerating feedwater (1) heaters:	-	3,794,400	131,130	118,073	808,721	4,852,323

*See page 70 for explanation of footnotes

TABLE X. - (Continued)

FERC Account Number	ECAS Report Ident. No(s).(2)	Account/Subdivision: Title	Account/Subdivision: Description/Specification	Material Costs: Major (3) Component	Material Costs: Balance (3) of Plant	Installation Cost (3)	Indirect Cost (4)	Contingency Allowance (5)	Total Cost
			Shell Press./Temp. psia/° F; Tube Press./Temp. psia/° F; Flow (100 Percent) lb/hr; Heat transfer area sq.ft.						
			LP#1 5/163; 210/158; 4.05×10^6; 14,330						
			LP#2 11/195; 210/190; 4.05×10^6; 13,550						
			LP#3 20/228; 210/223; 4.05×10^6; 13,720						
			LP#4 67/300; 210/295; 4.05×10^6; 18,770						
			IP 296/416; 1040/415; 6.22×10^6; 45,660						
			HP 745/510; 5700/519; 6.22×10^6; 49,700						
			DFH 6.22×10^6 lb/hr @ 353° F						
312.62	-	Water Treatment System	- - -	Included in Subdivision 311.9					
312.7	-	Effluent Control	Total Subdivision 312.7	7,626,000	6,051,200	3,540,510	3,187,967	4,081,136	24,486,813
312.71	1.3, F-11, Table 14	Precipitators and Breeching (4 reqd.)	Total Subdivision 312.71	7,626,000	272,800	1,500,710	1,351,278	2,150,156	12,900,945
			54 ft. high x 92 ft. wide x 44 ft. long each, 1,262,000 lb, 1296 kVA, 99 percent particulate removal efficiency, 695,000 acfm @ 300° F, including support steel						
312.72	3.6, F-16	Chimney	Total Subdivision 312.72	-	1,946,800	1,646,410	1,482,470	1,015,136	6,090,816
			Concrete stack and liner; lights and marker painting; hoists and platforms; stack foundation 40 ft. I.D., 500 ft. high						
312.73	-	Stack Gas Reheat System	Total Subdivision 312.73	-	3,831,600	393,390	354,219	915,042	5,495,051
	3.14, F-15 (8)	Forced draft fans for reheater air (6 reqd. @ $240,000 ea.)	Operating: 545,000 cfm @ 80° F, Total S.P. = 3.5 in. w.g. Test block: 654,000 cfm @ 105° F, Total S.P. = 4.55 in. w.g. Motor: 650 hp	-	1,618,200	189,410	170,550	395,632	2,373,792
	3.14, F-13 (8)	Stack gas reheat air heaters (6 reqd. @ $347,200 ea.)	4.5 ft. high, 21.5 ft. wide x 37.5 ft. long each	-	2,213,400	203,980	183,669	520,215	3,121,259

*See pages 70 and 71 for explanation of footnotes

TABLE X. - (Continued)

FERC Account Number	ECAS Report Ident. No(s).(2)	Account/Subdivision Title	Account/Subdivision Description/Specification	Material Costs Major (3) Component	Material Costs Balance (3) of Plant	Installation Cost (3)	Indirect Cost(4)	Contingency Allowance(5)	Total Cost
312.8	-	**Flue Gas Desulfurization System**	Total Subdivision 312.8	-	29,028,400	8,025,420	7,950,235	9,161,611	54,965,666
312.81	-	FGD Equipment	Total Subdivision 312.81	-	13,951,600	5,245,200	4,722,912	5,983,942	35,903,654
	3.15, F-12	Wet lime SO_2 scrubbers (turbulent contact absorber) (6 reqd. @ [illegible] ea.)	Complete SO_2 scrubber vessels with pre-saturator and mist eliminator systems. 60ft. high x 40 ft. wide x 18ft. long, 316L stainless steel, neoprene lined, 3 stages, 450,000 acfm @ 312° F each	-	8,593,200	1,253,020	1,128,251	2,194,894	13,169,365
	3.13	Scrubber ductwork	Flue gas duct outboard of electrostatic precipitators, duct lining, duct insulation, dampers & expansion joints	-	4,054,800	3,015,990	2,715,674	1,957,293	11,743,757
	3.17	Scrubber system pumps	Slurry recycle (18 @ $49,600 ea.); mist eliminator wash (3 @ $31,000 ea.); slurry storage and transfer $4,900 ea.); slurry feed (3 @ $6,200 ea.); pond feed tank (3 @ $12,400 ea.); pond feed booster (2 @ $18,600 ea.); pond water recycle and booster (4 @ $15,500 ea.)	-	1,339,200	145,700	131,192	323,218	1,939,310
	3.18	Scrubber system tanks	Tanks and agitators for absorber effluent hold, pond feed, entrainment separator surge, slurry surge, slurry storage and slurry transfer	-	2,703,200	58,200	52,477	562,791	3,376,708

*See page 70 for explanation of footnotes

TABLE X. - (Continued)

FERC Account Number	ECAS Report Ident. No(s).(2)	Account/Subdivision Title	Description/Specification	Material Costs: Major (3) Component	Material Costs: Balance (3) of Plant	Installation Cost (3)	Indirect Cost(4)	Contingency Allowance(5)	Total Cost
	6.2	Scrubber system large piping	Makeup water, re-saturation slurry water, mist eliminator wash, absorber slurry effluent tank overflow, pond feed, pond recycle water, lime slurry, recycle slurry, air heater steam, supply, and air heater condensate return piping	-	3,261,200	772,210	695,318	945,746	5,674,473
312.82	5.5	Foundations and Structural	Total Subdivision 312.82	-	4,538,400	2,622,600	2,361,456	1,904,491	11,426,947
			Foundations earth-work and structures particular to scrubber equipment						
312.83	3.16, C-13, C-14, C-15	Lime Manufacturing System (traveling grate kiln @ $3,348,000, lime slaker @$148,800)	Total Subdivision 312.83	-	4,538,400	961,620	865,267	1,273,177	7,639,065
			Limestone calciner: 650tons/day, nominal (880 tons/day, design), 12 ft. wide x 48ft. long traveling grate, 13ft. I.D. x 180ft. long rotary kiln with Niems-type cooler, coal conveyor, bucket elevator and storage bin, coal grinding/firing equipment, control panel/instrumentation, refractories, drives, induced draft fan, baghouse dust collector and ducting, kiln stack, lime conveyor bucket elevator, storage silos and lime slaker						
	-	Limestone handling system excavations, foundations, conveyors, etc.	- - -			Included in Subdivisions 312.1 & 312.1			

*See page 70 for explanation of footnotes

TABLE X. - (Continued)

FERC Account Number	ECAS Report Ident. No(s).(2)	Account/Subdivision Title	Description/Specification	Material Costs Major Component (3)	Material Costs Balance of Plant (3)	Installation Cost (3)	Indirect Cost (4)	Contingency Allowance (5)	Total Cost
314.	-	STEAM TURBINE - GENERATOR AND AUXILIARIES	Total Account 314.	33,020,000	24,641,200	18,772,505	16,903,243	18,707,390	112,244,337
314.1	2.0, Table 14, Fig. 5 Table 24	Steam Turbine and Auxiliaries	Total Subdivision 314.1	33,020,000	127,000	1,790,700	1,612,392	7,310,018	43,860,110
			820 MWe guaranteed generator output; tandem compound 4 flow turbine with 33.5 in. last stage buckets; 2.3" Hg abs.; 3500 psig/1000° F throttle steam, 1000° F/675 psig reheat steam; 15.4 percent continuous extraction for stack gas reheat; exciter; 992 MVA generator @ 75 psig hydrogen pressure; 0.9 pf. Hydrogen, lube oil and seal oil systems, stop-throttle valves, cross-over piping, insulation, motors for auxiliaries.						
314.2	3.4, F-1	Condenser & Auxiliaries	Total Subdivision 314.2	-	2,692,400	239,760	214,966	629,229	3,775,375
			Shells, tubes, air ejectors at 2.3 in. Hg (abs.) 3.31 x 10[5] sq.ft. of heat transfer area, 3.93x10[6] pph						
314.3	-	Circulating Water System	Total Subdivision 314.3	-	5,473,700	2,163,763	1,948,307	1,917,154	11,502,923
314.31	-	Pumps, Valves, Piping and Structure	Total Subdivision 413.31	-	889,000	44,768	40,310	194,815	1,168,893
	3.2, F-7	Circulating water pumps and motors (3 @ $279,400)	82,000 gpm, 2250 hp, 75ft. TDH each	-	889,000	44,768	40,310	194,815	1,168,893
	5.4	Circulating water valves, piping & structure	- - -	Included in Subdivision 314.32					

*See page 70 for explanation of footnotes

TABLE X. - (Continued)

FERC Account Number	ECAS Report Ident. No(s). (2)	Account/Subdivision		Material Costs		Installation Cost (3)	Indirect Cost (4)	Contingency Allowance (5)	Total Cost
		Title	Description/Specification	Major (3) Component	Balance (3) of Plant				
314.32	-	Cooling Towers	Total Subdivision 314.32	-	4,584,700	2,118,995	1,907,997	1,722,33[illegible]	10,334,031
	3.11, F-8	Tower Structure (20 cells)	Mechanical draft towers with fans and motors	-	2,832,100	775,970	698,703	861,355	5,168,128
	5.4, F-2	Tower basin & circulating water system	Circulating water pump pads, riser and concrete envelope for pipe; cooling tower basin; circulating water pipe (I.D. = 114 in.) & valves; misc. steel & fire protection. 246,000 gpm	-	1,752,600	1,343,025	1,209,294	860,984	5,165,903
314.4	-	<u>Steam Piping Systems</u>	Total Subdivision 314.4	-	14,439,900	14,131,608	12,724,460	8,259,194	49,555,161
314.41	6.1, F-2	Main Steam	Total Subdivision 314.41 Main steam (I. D. = 15.3 in., t_m=3.97 in); hot reheat (I.D.=18.1 in., t_m=2.25 in); cold reheat (I.D.=32.54 in., t_m=1.57 in); feedwater (I.D.=26.54 in., 0.675 in.) and condensate large piping, valves and fittings.	-	4,889,500	1,208,723	1,088,365	1,437,317	8,623,905
314.42	6.3	Auxiliary Steam	- - -	Included in Subdivision 314.43					
314.43	-	Miscellaneous Piping Systems	Total Subdivision 314.43	-	9,550,400	12,922,886	11,636,096	6,821,876	40,931,257
	6.3	Other large piping	Auxiliary steam, process water, auxiliary systems	-	5,143,500	3,447,098	3,103,855	2,338,890	14,033,343
	6.4	Small piping	All piping, valves and fittings of 2 in. diameter and less	-	1,714,500	2,268,220	2,042,363	1,205,017	7,230,100
	6.5	Hangers and miscellaneous labor operations	All hangers and supports; material handling; scaffolding and associated miscellaneous labor operations	-	1,854,200	6,767,450	5,643,372	2,753,004	16,518,026
	6.6	Pipe insulation	- - -	-	838,200	940,118	846,506	524,965	3,149,788

*See page 70 for explanation of footnotes

TABLE X. - (Continued)

FERC Account Number	ECAS Report Ident. No(s). (2)	Account/Subdivision: Title	Account/Subdivision: Description/Specification	Material Costs: Major (3) Component	Material Costs: Balance (3) of Plant	Installation Cost (3)	Indirect Cost (4)	Contingency Allowance (5)	Total Cost
314.5	3.12	Other Turbine Plant & Mechanical Equipment	Total Subdivision 314.5	-	2,106,200	447,675	403,098	591,795	3,550,768
			Water treatment & chemical injection, air compressors & auxiliaries; fuel oil handling system, ignition & warmup; screenwell; misc. plant equipment & motors, & equipment insul.						
315.	-	ACCESSORY ELECTRIC EQUIPMENT	Total Account 315.	-	13,382,400	15,261,840	13,742,150	8,477,272	50,863,668
315.1	4-2	Station and Auxiliary Transformers	Total Subdivision 315.1	-	1,574,400	245,693	221,228	408,264	2,449,584
			Station service and startup transformers; service transformers for boiler and scrubber systems; generator main bus as follows:						
	E-2	Unit Auxiliary Transformers (2 reqd.)	40/54/67 MVA, 65° C, OA/FA/FOA, 24/13.8 kV, 3-phase, 60Hz	-	-	-	-	-	-
	E-4	Startup Transformer	28/37.5/47 MVA, OA/FA/FOA, 500/13.8 kV, 65° C, 3-phase 60Hz	-	-	-	-	-	-
	E-6	Boiler Auxiliary Transformers (2 reqd.)	5500 kVA, OA, 65° C, 13.8/4.16 kV, 3-phase, 60Hz	-	-	-	-	-	-
	E-8	Scrubber Transformers (2 reqd.)	5000 kVA, OA, 65° C, 13.8/4.16 kV, 3-phase, 60 Hz	-	-	-	-	-	-
315.2	-	Miscellaneous Motors	- - -	Included in Subdivision 314.5					

*See page 70 for explanation of footnotes

TABLE X. - (Continued)

FERC Account Number	ECAS Report Ident. No(s). (2)	Account/Subdivision: Title	Account/Subdivision: Description/Specification	Material Costs: Major (3) Component	Material Costs: Balance (3) of Plant	Installation Cost (3)	Indirect Cost (4)	Contingency Allowance (5)	Total Cost
315.3	4.3	Switchgear & Motor Control Centers	Total Subdivision 315.3	-	[illegible]	657,000	546,503	1,067,114	[illegible]
			Switchgear, switchyard & load centers; motor control centers; local control stations; distribution panels, relay & meter boards; & the following transformers:						
	E-5	Misc. 480 V load control center transformers (14 reqd.)	1689 kVA, OA, 65° C, 13.8kV/480 V/277 V, 3-phase, 60Hz	-	-	-	-	-	-
	E-7	Local control center transformers (2 reqd.)	7000 kVA, OA, 65° C, 13.8/4.16 kV, 3-phase, 60Hz	-	-	-	-	-	-
315.4	4.6	Conduit, Trays, Wire, Cable and Bussework	Total Subdivision 315.4	-	5,081,400	9,133,030	6,224,462	4,475,370	26,852,219
315.5	4.4	Miscellaneous Electrical Equipment	Total Subdivision 315.5		2,472,300	5,246,258	4,723,864	2,488,484	14,930,906
			Communications; grounding; cathodic & freeze protection; lighting; pre-operational testing						
315.6	-	Integrated Control System	- - -	Included in Subdivision 312.42					
315.7	-	Data Acquisition System	- - -	Included in Subdivision 312.42					
315.8	4.5, E-3	Emergency Power System	Total Subdivision 315.8	-	135,300	28,905	26,027	38,046	228,278
			Diesel generator, batteries & associated d.c. equipment. 1000 KW, 3-phase, 60 Hz, 480 V, 0.8 pf.						
316.	-	MISCELLANEOUS POWER PLANT EQUIPMENT	Total Account 316.	-	350,000	14,686	13,225	75,583	453,495
316.1	-	Fuel Oil Handling System	- - -	Included in Subdivision 314.5					
316.2	-	Fire Protection System	- - -	Included in Subdivision 311.14					
316.3	7.6	Machine & Maintenance Shops	- - -	-	350,000	14,686	13,225	75,583	453,495

*See page 70 for explanation of footnotes

TABLE X. - (Concluded)

FERC Account Number	ECAS Report Ident. No(s) (2)	Account/Subdivision		Material Costs		Installation Cost (3)	Indirect Cost (4)	Contingency Allowance (5)	Total Cost
		Title	Description/Specification	Major Component (3)	Balance of Plant (3)				
350.	-	TRANSMISSION PLANT	Total Account 350.	-	2,323,000	54,050	48,668	485,144	2,910,862
350.1	5.1, 5.2, 5.3	Structures & Improvements	- - -	Included in Subdivision 311.3					
350.2	4.1, E-1	Main Transformers	Total Subdivision 350.2 468 MVA, FOA, 65°	-	2,323,000	54,050	48,668	485,144	2,910,862
350.3	4.3	Switchyard	- - -	Included in Subdivision 315.3					
		Total of Direct Accounts 310. to 350.		89,911,200	12[illegible],219,920	81,058,963	7[illegible],587,261	74,635,470	447,812,814
		A/E Services & Fee @ 18 percent of Balance of Plant Materials, Installation & Indirect Costs (9)							50,987,906
		Plant Capital Cost							498,800,720
		Escalation & Interest During Construction @ 54.8 percent (5.5 yr. Constr. per. 6.5 percent escalation rate, 10 percent interest rate) (10)							273,342,795
		Total Plant Capital Cost in Jan. 1984 Dollars							772,143,515
		Total Plant Capital Cost De-Escalated to mid-1978 (11)							546,103,784

*See pages 70 and 71 for explanation of footnotes

NOTES TO TABLE X

(1) Based on ECAS report tables 15 and 16 (Ref. 7).

(2) Identification numbers consisting of letters and numerals refer to table 15 of the ECAS report, reproduced in Appendix C, pages 178 to 180, for reference. Identification numbers consisting of numerals only refer to table 16 of the ECAS report, reproduced in Appendix C, pages 181 to 187, for reference. References to other ECAS report tables are as indicated.

(3) Escalated from the mid-1975 value listed in table XXXII using the account specific escalation factor listed in table XXV.

(4) See Note 3.

(5) Based on the 20 percent contingency rate included in the ECAS report (Ref. 7, page 44).

(6) The costs of the buildings, structures and excavations listed in Accounts 311.3, 311.4, 311.6, 311.7, 311.9 and 312.1 are calculated using the estimated percentages of the sum of the costs of Items 5.1, 5.2 and 5.3 of Ref. 7, table 16, listed in Appendix C, page 199, table XXX, escalated to mid-1978 dollars using the account specific escalation factors for Accounts 311. and 312., where appropriate, listed in table XXV. Note that the same table applies to both the 250° and 175° F (394° and 353° K) reheat cases.

(7) The separate balance-of-plant materials costs for the feedwater booster (2) and main feedwater (3) pumps are estimated from the combined balance-of-plant materials cost of these five pumps ($3,220,000), listed in Ref. 7, table 16, as follows: The combined equipment cost of the pumps $3,070,000 ((2)x($125,000) + (3)x($940,000)) is substracted from the combined balance-of-plant materials cost and the remainder ($150,000) divided by the total horsepower of the five pumps (45,500 hp) resulting in $3.30/hp. This cost per horsepower is then multiplied by the horsepower of the two feedwater booster pumps, for example,

NOTES TO TABLE X (Concluded)

to give \$25,410 (7700 hp x \$3.30/hp) and the equipment cost of the two pumps, \$250,000, added to the product to give \$275,410. This figure is then escalated to mid-1978 dollars (\$341,500) using the 1.24 factor for FERC Account 312. listed in table XXV. Similarly the cost of the main feedwater pumps is estimated as \$2,944,740 (i.e., (\$3.30/hp)x(38,700 hp) + (\$940,000)), which is escalated to \$3,651,500.

(8) The separate balance-of-plant materials costs for the stack gas reheat system forced draft fans and reheat air heaters are estimated from the combined \$3,090,000 balance-of-plant materials cost listed in Ref. 7, table 16, as follows: The combined equipment cost of the fans and heaters, \$2,880,000 (6 x \$200,000 + 6 x \$280,000), is subtracted from the combined balance-of-plant materials cost. The remainder, \$210,000, is divided equally between the fans and heaters, and one \$105,000 part is added to the equipment cost of the fans and the other to the equipment cost of the heaters to give \$1,305,000 and \$1,785,000 for the respective balance-of-plant materials cost of each. These values are escalated to mid-1978 dollars (\$1,618,200 and \$2,213,400, respectively) using the 1.24 factor for FERC Account 312. listed in table XXV.

(9) Includes the 20 percent contingency in Note 5 applied to the 15 percent A/E services and fee rate employed in the ECAS report (Ref. 7, page 44) to account for the change in the order of applying the contingency and A/E services and fee rates in this study compared to the ECAS study.

(10) Based on the guidelines specified by NASA for the ECAS study (Ref. 4).

(11) The sum of the Plant Capital Cost and Escalation and Interest During Construction divided by $(1.065)^{5.5}$ to de-escalate the Total Plant Capital cost in Jan. 1984 at the completion of the 5.5 year construction period to mid-1978.

TABLE XI. - ECAS REFERENCE CONVENTIONAL FURNACE COAL-FIRED POWER PLANT WITH WET SO_2 SCRUBBER CAPITAL COST ESTIMATE DETAILS AS OF MID-1978 (175° F Stack Gas Reheat Temperature (1)) (Mid-1978 Dollars)

FERC Account Number	ECAS Report Ident. No(s).(2)	Account/Subdivision		Material Costs		Installation Cost (3)	Indirect Cost (4)	Contingency Allowance (5)	Total Cost
		Title	Description/Specification	Major (3) Component	Balance (3) of Plant				
310.	-	LAND AND LAND RIGHTS	- - -			Not Included	in Study		
311.	-	STRUCTURES AND IMPROVEMENTS (6)	Total Account 311.	-	13,155,560	12,304,700	11,077,954	7,307,643	43,845,857
311.1	7.0	Improvements to Site	Total Subdivision 311.1	-	1,647,200	3,530,170	3,178,655	1,671,205	10,027,230
311.11	7.1	Site Preparation and Improvements	Soil testing, clearing and grubbing, rough grading, finish grading, landscaping	-	11,600	1,185,810	1,067,734	453,029	2,718,172
311.12	7.2	Site Utilities	Storm and sanitary sewers, non-process service water	-	58,000	68,150	61,364	37,503	225,017
311.13	7.3	Roads and Railroads	Railroad spur, roads, walks and parking areas	-	859,400	368,010	331,366	311,555	1,869,331
311.14	7.4	Yard and Plant Fire Protection, Fences and Gates	- - -	-	696,000	708,760	638,186	408,589	2,451,535
311.15	7.5	Water Treatment Ponds	Earthwork, pond lining, off-site pipeline	-	23,200	1,199,440	1,080,006	460,529	2,763,176
311.3	-	Main (Turbine-Generator) Building	Total Subdivision 311.3	-	2,822,280	2,234,160	2,011,440	1,413,576	8,481,456
311.31	5.1,5.3	-	Excavation, substructure, de-watering and piling, including excavation and substructure for transmission plant switch-yard	-	-	-	-	-	-
311.32	5.2	-	Building structure and services	-	6,927,520	5,483,320	4,936,960	3,469,560	20,817,360
311.4	-	Steam Generator Building	Total Subdivision 311.4	-	-	-	-	-	-
311.41	5.1,5.3	-	Excavation, substructure, de-watering and piling	-	-	-	-	-	-
311.42	5.2	-	Enclosure structure and services	-	-	-	-	-	-

*See page 86 for explanation of footnotes

TABLE XI. - (Continued)

FERC Account Number	ECAS Report Ident. No(s).(2)	Account/Subdivision: Title	Account/Subdivision: Description/Specification	Material Costs: Major (3) Component	Material Costs: Balance (3) of Plant	Installation Cost (3)	Indirect Cost (4)	Contingency Allowance (5)	Total Cost
311.6	-	Maintenance, Service, Warehouse and Office Building (Service Building)	Total Subdivision 311.6	-	962,800	762,120	685,560	482,096	2,892,576
311.61	5.1,5.3	-	Excavation, substructure, dewatering and piling	-	-	-	-	-	-
311.62	5.2	-	Building Structure and services	-	-	-	-	-	-
311.7	5.1,5.3	Other Buildings	Total Subdivision 311.7 Excavation and structure for makeup water intake	-	256,360	203,000	183,280	128,528	771,168
311.8	3.7	Cranes and Hoists	Total Subdivision 311.8 Crane and accessories in turbine hall	-	475,600	40,890	36,018	110,662	663,970
311.9	5.1,5.2	On-site Waste Treatment (Including Water Treatment) Building	Total Subdivision 311.9 Excavation, substructure building structure and services; lime, alum, ion exchange resin, acid, caustic and chlorine storage tanks; reagent metering and feeding pumps; mixers; clarifiers	-	63,800	51,040	45,240	32,016	192,096

*See page 86 for explanation of footonotes

TABLE XI. - (Continued)

FERC Account Number	ECAS Report Ident. No(s).(2)	Account/Subdivision		Material Costs		Installation Cost (3)	Indirect Cost (4)	Contingency Allowance(5)	Total Cost
		Title	Description/Specification	Major (3) Component	Balance (3) of Plant				
312.	-	<u>BOILER PLANT (3)</u>	Total Account 312.	55,991,200	70,133,360	32,655,090	29,404,689	37,816,868	226,001,207
312.1	3.8, 5.1, 5.3	<u>Coal Handling</u>	Total Subdivision 312.1 Coal, limestone and ash handling excavations, foundations pits and tunnels. Also, railcar dumping equipment, dust collectors, primary and secondary crushing equipment, belt scale, sampling station, magnetic cleaners, mobile equipment, coal silos, reclaiming feeders, and the following conveyors to coal pile and coal silos:	-	8,914,360	2,407,770	2,169,231	2,698,272	16,189,633
312.11	-	Unloading and Yard Storage	- - -	-	-	-	-	-	-
	C-1	Coal Conveyor belt	60 in. wide, 340 ft. long, 3000 tph	-	-	-	-	-	-
	C-2	Coal Conveyor belt	60 in. wide, 760 ft. long, 3000 tph	-	-	-	-	-	-
	C-3	Coal Conveyor belt	60 in. wide, 190 ft. long, 3000 tph	-	-	-	-	-	-
312.12	-	Reclaim and Delivery	- - -	-	-	-	-	-	-
	C-4	Coal Conveyor belt	42 in. wide, 980 ft. long, 500 tph	-	-	-	-	-	-
	C-5	Coal Conveyor belt	42 in. wide, 540 ft. long, 500 tph	-	-	-	-	-	-
	C-6	Coal Conveyor belt	42 in. wide, 170 ft. long, 500 tph	-	-	-	-	-	-
	C-7	Coal Conveyor belt	42 in. wide, 110 ft. long, 500 tph	-	-	-	-	-	-
	C-8	Coal Conveyor belt (2 reqd.)	30 in. wide, 160 ft. long, 300 tph	-	-	-	-	-	-

*See page 86 for explanation of footnotes

TABLE XI. - (Continued)

FERC Account Number	ECAS Report Ident. No(s).(2)	Account/Subdivision		Material Costs		Installation Cost (3)	Indirect Cost (4)	Contingency Allowance (5)	Total Cost
		Title	Description/Specification	Major (3) Component	Balance (3) of Plant				
312.2	3.10	Slag and Ash Handling	Total Account 312.2	-	4,439,200	888,770	800,271	1.225,648	7,353,889
			Bottom ash system, fly ash handling system for precipitators and air pre-heater, ash conveyors, railcar loading equipment, ash hoppers, sluice pumps and drives, piping, clinker grinder, pressure blowers, valves and piping, and the following storage silos and associated equipment:						
312.21	C-16	Fly ash storage silos (2 reqd.)	feeders, unloaders and foundations, silos: total volume 833,184 cu. ft., 85 ft. high, 80 ft. dia.	-	-	-	-	-	-
312.3	3.9	Limestone Handling	Total Subdivision 312.3	-	1,550,000	320,540	288,622	431,832	2,590,995
			Magnetic cleaners, reclaiming feeders, belt scale, and the following conveyors to limestone pile and calciner:						
312.31	-	Conveyors		-	-	-	-	-	-
	C-9	Limestone Conveyor belt	60 in. wide, 500 ft. long, 3000 tph	-	-	-	-	-	-
	C-10	Limestone Conveyor belt	24 in. wide, 630 ft. long, 65 tph	-	-	-	-	-	-
	C-11	Limestone Conveyor belt	24 in. wide, 420 ft. long, 65 tph	-	-	-	-	-	-
	C-12	Limestone bucket Conveyor	24 in. wide, 120 ft. long, 100 tph	-	-	-	-	-	-
312.4	-	Steam Generator Equipment	Total Subdivision 312.4	49,265,200	16,492,000	18,299,920	16,477,715	20,106,967	120,641,802
312.41	1.1, Table 14	Steam Generator	Heat transfer surface and pressure parts; buckstays, braces and hangers; fuel-burning equipment, accessories, soot and ash equipment; control systems, brick-work, refractory and insulation; support steel & misc. materials; primary air fans & feedwater piping	49,265,200	8,432,000	12,238,800	11,020,128	16,191,226	97,147,354

*See page 86 for explanation of footnotes

TABLE XI. - (Continued)

FERC Account Number	ECAS Report Ident. No(s). (2)	Account/Subdivision Title	Account/Subdivision Description/Specification	Material Costs: Major (3) Component	Material Costs: Balance (3) of Plant	Installation Cost (3)	Indirect Cost (4)	Contingency Allowance (5)	Total Cost
312.42	6.7	Instrumentation and Controls	Integrated boiler controls, boiler/turbine coordinating controls, main mech. system control boards, sampling system includ analyzers and sampling panel, stack emissions monitoring system and data acquisition system	-	5,976,800	3,190,830	2,873,105	2,408,147	14,448,882
312.43	1.2	Auxiliaries	Air preheater; flues and ducts to precipitators; insulation for flues and ducts; pulverizers, feeders and hoppers; and the following fans:	-	2,083,200	2,870,290	2,584,482	1,507,594	9,045,567
	F-9	Forced draft fans (2 reqd. @ $483,600 ea.)	Operating: 971,000 cfm @ 80° F, S.P. outlet = 19 in. w.g. Test block: 1,165,000 cfm @ 105° F, S.P. outlet=24.7 in. w.g. Motor: 6,500 hp	-	-	-	-	-	-
	F-10	Primary air fans (2 reqd.)	Operating: 161,750 cfm @ 96° F, S.P. inlet= 19 in. w.g., S.P. outlet = 42 in. w.g. Test Block: 194,000 cfm @ 121° F, S.P. inlet=19 in. w.g., S.P. outlet=54.6 in. w.g. Motor: 2,250 hp	(Included in Subdivision 312.41)					
	F-14	Induced draft fans (4 reqd. @ $272,800 ea.)	Operating: 660,000 cfm @ 300° F, Total S.P. = 23 in. w.g. Test block: 800,000 cfm @ 325° F, Total S.P.=30 in. w.g. Motor: 5,000 hp	-	-	-	-	-	-

*See page 86 for explanation of footnotes

TABLE XI. - (Continued)

FERC Account Number	ECAS Report Ident. No(s), (2)	Account/Subdivision Title	Account/Subdivision Description/Specification	Material Costs Major Component (3)	Material Costs Balance of Plant (3)	Installation Cost (3)	Indirect Cost (4)	Contingency Allowance (5)	Total Cost
312.5	-	Auxiliary Boiler System	Optional (not included)	-	-	-	-	-	-
312.6	-	Other Boiler Plant Systems	Total Subdivision 312.6	-	8,742,200	349,680	314,861	1,881,349	11,288,039
312.61	-	Condensate and Feedwater System	Total Subdivision 312.61	-	8,742,200	349,680	314,861	1,881,349	11,288,089
	3.3, P-4	Main condensate pumps & motors (2 reqd. @ $117,800 ea.)	Vertical centerline, 510* gpm, 750 hp motor, 410 ft. TDH (Other pumps and drivers not listed elsewhere)	-	330,800	72,850	65,596	193,849	1,163,095
	3.1, P-5 (7)	Feedwater booster pumps and motors (2 reqd. @ $155,000 ea.)	7,300 gpm, 3850hp, 1510 ft. TDH	-	341,500	29,140	26,238	79,376	476,254
	3.1, P-6 (7)	Main boiler feed pumps and turbine drives (3 reqd. @ $1,165,600 ea.)	4900 gpm, 12,600 hp, 8300 ft. TDH	-	3,651,500	116,560	104,954	774,603	4,647,617
	P-2	Boiler feedwater piping	- - -	Included in Subdivision 314.41					
	3.5, P-3	Feedwater heaters	Miscellaneous heaters and exchangers; tanks and vessels; and the following low pressure (4), intermediate pressure (1) and deaerating feedwater (1) heaters:	-	3,918,400	131,130	118,073	833,521	5,001,123
312.62	-	Water Treatment System	- - -	Included in Subdivision 311.9					
312.7	-	Effluent Control	Total Subdivision 312.7	7,626,000	2,926,400	2,855,720	2,571,363	3,195,897	19,175,380

	Shell Press./Temp. psia/° F	Tube Press./Temp. psia/° F	Flow (100 Percent lb/hr	Heat transfer area sq.ft.
LP01	5/163	210/158	4.75×10^6	17,170
LP02	11/195	210/190	4.75×10^6	16,260
LP03	20/228	210/223	4.75×10^6	16,600
LP04	67/300	210/295	4.75×10^6	22,710
IP	296/416	1040/415	6.22×10^6	45,660
HP	745/510	5700/519	6.22×10^6	49,700
DFH	6.22×10^6 lb/hr @ 353° F			

*See page 86 for explanation of footnotes

TABLE XI. - (Continued)

FERC Account Number	ECAS Report Ident. No(s). (2)	Account/Subdivision		Material Costs*		Installation Cost (3)	Indirect Cost (4)	Contingency Allowance (5)	Total Cost
		Title	Description/Specification	Major (3) Component	Balance (3) of Plant				
312.71	1.3, F-11, Table 14	Precipitators and Breeching (4 reqd.)	Total Subdivision 312.71	7,626,000	272,300	1,500,710	1,351,278	2,150,158	12,900,945
			54 ft. high x 92 ft. wide x 44 ft. long each, 1,262,000 lb, 1296 kVA, 99% particulate removal efficiency, 695,000 acfm @ 300° F, including support steel						
312.72	3.6, F-16	Chimney	Total Subdivision 312.72	-	1,537,600	1,253,020	1,128,251	783,774	4,702,645
			Concrete stack and liner; lights and marker painting; hoists and platforms; stack foundation 27 ft. I.D., 500 ft. high						
312.73	-	Stack Gas Reheat System	Total Subdivision 312.73	-	1,116,000	101,990	91,834	261,965	1,571,789
	3.14, F-15 (8)	Forced draft fans for reheater air (6 reqd. @ $[illegible] ea.)	Operating: 123,000 cfm @ 80° F, Total S.P. = 3.5 in. w.g. Test block: 147,000 cfm @ 105° F, Total S.P. = 4.55 in. w.g. Motor: 150 hp	-	688,200	43,710	39,358	154,254	925,521
	3.14, F-13 (8)	Stack gas reheat air heaters (6 required @ $62,[illegible] ea.)	2.5 ft. high, 18.2 ft. wide x 10.7 ft. long each	-	427,800	58,280	52,477	107,711	646,268

*See pages 86 and 87 for explanation of footnotes

TABLE XI. - (Continued)

FERC Account Number	ECAS Report Ident. No(s).(2)	Account/Subdivision: Title	Account/Subdivision: Description/Specification	Material Costs: Major (3) Component	Material Costs: Balance (3) of Plant	Installation Cost (3)	Indirect Cost(4)	Contingency Allowance(5)	Total Cost
312.8	-	Flue Gas Desulfurization System	Total Subdivision 312.8	-	27,069,200	7,532,690	6,782,626	8,276,903	49,661,419
312.81	-	FGD Equipment	Total Subdivision 312.81	-	17,992,400	3,948,470	3,555,303	5,099,235	30,595,408
	3.15, P-12	Wet lime SO_2 scrubbers (turbulent contact absorber) (6 reqd. @ $1,2[illegible]0,000 ea.)	Complete SO_2 scrubber vessels with pre-saturator and mist eliminator systems. 60ft. high x 40 ft. wide x 18ft. long, 316L stainless steel, neoprene lined, 3 stages, 450,000 acfm @ 312° F each	-	8,593,200	1,253,020	1,128,251	2,194,894	13,169,365
	3.13	Scrubber ductwork	Flue gas duct outboard of electro-static precipitators, duct lining, duct insulation, dampers & expansion joints	-	2,418,000	1,748,400	1,574,304	1,148,141	6,888,845
	3.17	Scrubber system pumps	Slurry recycle (18 @ $49,600 ea.); mist eliminator wash (3 @ $31,000 ea.); slurry storage and transfer (4 @ $4,960 ea.); slurry feed (3 @ $6,200 ea.); pond feed tank (3 @ $12,400 ea.), pond feed booster (2 @ $13,600 ea.); pond water recycle and booster (4 @ $15,500 ea.)	-	1,339,200	145,700	131,192	323,218	1,939,310
	3.18	Scrubber system tanks	Tanks and agitators for absorber effluent hold, pond feed, entrainment separator surge, slurry surge, slurry storage and slurry transfer	-	2,703,200	58,290	52,477	562,791	3,376,748

*See page 86 for explanation of footnotes

TABLE XI. - (Continued)

FERC Account Number	ECAS Report Ident. No(s).(2)	Account/Subdivision: Title	Account/Subdivision: Description/Specification	Material Costs: Major (3) Component	Material Costs: Balance (3) of Plant	Installation Cost (3)	Indirect Cost(4)	Contingency Allowance(5)	Total Cost
	6.2	Scrubber system large piping	Makeup water, re-saturation slurry water, mist eliminator wash, absorber slurry effluent tank overflow, pond feed, pond recycle water, lime slurry, recycle slurry, air heater steam, supply, and air heater condensate return piping	-	2,938,800	743,070	669,079	870,190	5,221,139
			Total Subdivision 312.82	-	4,538,400	2,622,600	2,361,456	1,904,491	11,426,947
312.82	5.5	Foundations and Structural	Foundations earthwork and structures particular to scrubber equipment						
			Total Subdivision 312.83	-	4,538,400	961,620	865,867	1,273,177	7,639,065
312.83	3.16, C-13, C-14, C-15	Lime Manufacturing System (traveling grate kiln @ $3,343,000; lime slaker $148,800)	Limestone calciner: 650tons/day, nominal (880 tons/day, design), 12 ft. wide x 48ft. long traveling grate, 13ft. I.D. x 180ft. long rotary kiln with Niems-type cooler, coal conveyor, bucket elevator and storage bin, coal grinding/firing equipment, control panel/instrumentation, refractories, drives, induced draft fan, baghouse dust collector and ducting, kiln stack, lime conveyor bucket elevator, storage silos and lime slaker			Included in Subdivisions 312.1 & 312.3			
	-	Limestone handling system excavations, foundations, conveyors, etc.	- - -						

*See page 86 for explanation of footnotes

TABLE XI. - (Continued)

FERC Account Number	ECAS Report Ident. No(s).(2)	Account/Subdivision: Title	Account/Subdivision: Description/Specification	Material Costs: Major (3) Component	Material Costs: Balance (3) of Plant	Installation Cost (3)	Indirect Cost (4)	Contingency Allowance (5)	Total Cost
314.	-	STEAM TURBINE - GENERATOR AND AUXILIARIES	Total Account 314.	33,972,500	26,060,400	19,100,800	17,198,848	19,266,510	115,599,058
314.1	2.0, Fig., 5 Table 24	Steam Turbine and Auxiliaries	Total Subdivision 314.1	33,972,500	127,000	1,790,700	1,612,392	7,500,518	45,003,110
			869 MW_e guaranteed generator output; tandem compound 4 flow turbine with 33.5 in. last stage buckets 2.3" Hg abs; 3500 psig/1000° F throttle steam, 1000° F/675 psig reheat steam 3.5 percent continuous extraction for stack gas reheat exciter, 992 MVA generator @ 75 psig hydrogen pressure; 0.9 pf. Hydrogen, lube oil and seal oil systems, stop-throttle valves, cross-over piping, insulation motors for auxiliaries						
314.2	3.4, F-1	Condenser & Auxiliaries	Total Subdivision 314.2	-	3,098,800	253,683	228,422	716,181	4,297,086
			Shells, tubes, air ejectors at 2.3 in. Hg (abs.), 3.97×10^5 sq.ft. of heat transfer area, 4.67×10^6 pph						
314.3	-	Circulating Water System	Total Subdivision 314.3	-	6,362,700	2,506,980	2,257,349	2,225,406	13,352,435
314.31	-	Pumps, Valves, Piping and Structure	Total Subdivision 413.31	-	952,500	44,768	40,310	207,515	1,245,093
	3.2, F-7	Circulating water pumps and motors (3 @ $298,450	95,000 gpm, 2500 hp, 75 ft. TDH each	-	952,500	44,768	40,310	207,515	1,245,093
	5.4	Circulating water valves, piping & structure	- - -	Included in Subdivision 314.32					

*See page 86 for explanation of footnotes

TABLE XI. - (Continued)

FDC Account Number	ECAS Report Ident. No(s).(2)	Account/Subdivision Title	Description/Specification	Material Costs Major(3) Component	Balance (3) of Plant	Installation Cost (3)	Indirect Cost (4)	Contingency Allowance(5)	Total Cost
314.32	-	Cooling Towers	Total Subdivision 314.32	-	5,410,200	2,462,213	2,217,039	2,017,890	12,107,342
	3.11, F-8	Tower Structure (20 cells)	Mechanical draft towers with fans and motors	-	3,276,600	895,350	806,196	995,629	5,973,775
	5.4, F-2	Tower basin & circulating water system	Circulating water pump pads, riser and concrete envelope for pipe; cooling tower basin; circulating water pipe (I.D. = 123 in.) & valves; misc. steel & fire protection. 246,000 gpm	-	2,133,600	1,566,863	1,410,843	1,022,261	6,133,567
314.4	-	Steam Piping Systems	Total Subdivision 314.4	-	14,363,700	14,101,763	12,697,587	8,232,610	49,395,659
314.41	6.1, F-2	Main Steam	Total Subdivision 314.41 Main steam (I.D. = 15.3 in., t_m=3.97in); hot reheat (I.D.=18.1 in., t_m=2.25 in.); cold reheat (I.D.=32.54 in., t_m=1.57 in.); feedwater (I.D.=26.53 in., 0.675 in.) and condensate large piping, valves and fittings.	-	4,889,500	1,208,723	1,088,365	1,437,317	8,623,905
314.42	6.3	Auxiliary Steam	- - -	Included in Subdivision 314.43					
314.43	-	Miscellaneous Piping Systems	Total Subdivision 314.43	-	9,474,200	12,893,040	11,609,222	6,795,292	40,771,755
	6.3	Other large piping	Auxiliary steam, process water, auxiliary systems	-	5,143,500	3,447,098	3,103,844	2,338,890	14,033,343
	6.4	Small piping	All piping, valves and fittings of 2 in. diameter and less	-	1,714,500	2,268,220	2,042,363	1,205,017	7,230,100
	6.5	Hangers and miscellaneous labor operations	All hangers and supports; material handling; scaffolding and associated miscellaneous labor operations	-	1,803,400	6,252,528	5,629,935	2,737,173	16,423,035
	6.6	Pipe insulation	- - -	-	812,800	925,195	833,069	514,213	3,085,277

*See page 86 for explanation of footnotes

TABLE XI. - (Continued)

FERC Account Number	ECAS Report Ident. No(s), (2)	Account/Subdivision: Title	Account/Subdivision: Description/Specification	Material Costs: Major (3) Component	Material Costs: Balance (3) of Plant	Installation Cost (3)	Indirect Cost (4)	Contingency Allowance (5)	Total Cost
314.5	3.12	Other Turbine Plant & Mechanical Equipment	Total Subdivision 314.5 Water treatment & chemical injection, air compressors & auxiliaries; fuel oil handling system, ignition & warmup; screenwell; misc. plant equipment & motors, & equipment insul.	-	2,108,200	447,675	403,098	591,795	3,550,768
315.	-	ACCESSORY ELECTRIC EQUIPMENT	Total Account 315.	-	13,382,400	15,261,[illegible]40	13,742,150	9,477,278	50,863,668
315.1	4-2	Station and Auxiliary Transformers	Total Subdivision 315.1 Station service and startup transformers; service transformers for boiler and scrubber systems; generator main bus as follows:	-	1,574,400	245,693	221,220	408,264	2,449,584
	E-3, 4	Unit Auxiliary Transformers (2 reqd.)	40/54/67 MVA, 65° C, OA/FA/FOA, 24/13.8 kV, 3-phase, 60Hz	-	-	-	-	-	-
	E-6	Startup Transformer	28/37.5/47 MVA, OA/FA/FOA, 500/13.8 kV, 65° C, 3-phase 60Hz	-	-	-	-	-	-
	E-21, 22	Boiler Auxiliary Transformers (2 reqd.)	5500 kVA, OA, 65° C, 13.8/4.16 kV, 3-phase, 60Hz	-	-	-	-	-	-
	E-25, 26	Scrubber Transformers (2 reqd.)	5000 kVA, OA, 65° C, 13.8/4.16 kV, 3-phase, 60 Hz	-	-	-	-	-	-
315.2	-	Miscellaneous Motors	- - -	Included in Subdivision 314.5					

*See page 86 for explanation of footnotes

TABLE XI. - (Continued)

FERC Account Number	ECAS Report Ident. No(s). (2)	Account/Subdivision Title	Account/Subdivision Description/Specification	Material Costs: Major (3) Component	Material Costs: Balance (3) of Plant	Installation Cost (3)	Indirect Cost (4)	Contingency Allowance (5)	Total Cost
315.3	4.3	Switchgear & Motor Control Centers	Total Subdivision 315.3	-	4,182,000	607,005	546,563	1,067,114	6,402,681
			Switchgear, switchyard & load centers; motor control centers; local control stations; distribution panels, relay & meter boards & the following transformers:						
	E-7, 20	Misc. 480 V load control center transformers (14 reqd.)	1689 kVA, OA, 65° C, 13.8kV/ 480 V/277 V, 3-phase, 60Hz	-	-	-	-	-	-
	E-23, 24	Local control center transformers (2 reqd.)	7000 kVA, OA, 65° C, 13.8/ 4.16 kV, 3-phase, 60Hz	-	-	-	-	-	-
315.4	4.6	Conduit, Cable Tray, Wire, Cable and Busswork	Total Subdivision 315.4	-	5,018,400	9,133,980	8,224,469	4,475,370	26,852,219
315.5	4.4	Miscellaneous Electrical Equipment	Total Subdivision 315.5	-	2,472,300	5,246,258	4,723,864	2,488,484	14,930,906
			Communications; grounding; cathodic & freeze protection; lighting; pre-operational testing						
315.6	-	Integrated Control System	- - -	Included in Subdivision 312.42					
315.7	-	Data Acquisition System	- - -	Included in Subdivision 312.42					
315.8	4.5, E-5	Emergency Power System	Total Subdivision 315.8	-	135,300	28,905	26,027	38,046	228,278
			Diesel generator, batteries & associated d.c. equipment. 1000 KW, 3-phase, 60 Hz, 480 V, 0.8 pf.						
316.	-	MISCELLANEOUS POWER PLANT EQUIPMENT	Total Account 316.	-	350,000	14,688	13,225	75,583	453,495
316.1	-	Fuel Oil Handling System	- - -	Included in Subdivision 314.5					
316.2	-	Fire Protection System	- - -	Included in Subdivision 311.14					
316.3	7.6	Machine & Maintenance Shops	- - -	-	350,000	14,688	13,225	75,583	453,495

*See page 86 for explanation of footnotes

TABLE XI. - (Concluded)

FERC Account Number	ECAS Report Ident. No(s).(2)	Account/Subdivision Title	Description/Specification	Material Costs Major (3) Component	Balance (3) of Plant	Installation Cost (3)	Indirect Cost (4)	Contingency Allowance (5)	Total Cost
350.	-	TRANSMISSION PLANT	Total Account 350.	-	2,323,000	54,050	48,668	485,144	2,910,862
350.1	5.1, 5.2, 5.3	Structures & Improvements	- - -	Included in Subdivision 311.3					
350.2	4.1, E-1.2	Main Transformers	Total Subdivision 350.2 468 MVA, FOA, 65°C, 24/500 kV	-	2,323,000	54,050	48,668	485,144	2,910,862
350.3	4.3	Switchyard	- - -	Included in Subdivision 315.3					
		Total of Direct Accounts 310. to 350.		90,863,700	125,404,720	79,391,168	71,485,535	73,429,025	440,574,148
		A/E Services & Fee @ 18 percent of Balance of Plant Materials, Installation & Indirect Costs (9)							49,730,656
		Plant Capital Cost							490,304,804
		Escalation & Interest During Construction @ 54.8 percent (5.5 yr. Constr. per. 6.5 percent escalation rate, 10 percent interest rate) (10)							268,687,033
		Total Plant Capital Cost in Jan. 1984 Dollars							758,991,837
		Total Plant Capital Cost De-escalated to mid-1978 (11)							536,802,170

*See pages 86 and 87 for explanation of footnotes

NOTES TO TABLE XI

(1) Based on ECAS report tables 27 and 28 (Ref. 7).

(2) Identification numbers consisting of letters and numerals refer to table 27 of the ECAS report, reproduced in Appendix C, pages 188 to 191, for reference. Identification numbers consisting of numerals only refer to table 28 of the ECAS report, reproduced in Appendix C, pages 192 to 198, for reference. References to other ECAS report tables are as indicated.

(3) Escalated from the mid-1975 value listed in table XXXIII using the account specific escalation factor listed in table XXV.

(4) See Note 3.

(5) Based on the 20 percent contingency rate included in the ECAS report (Ref. 7, page 44).

(6) The costs of the buildings, structures and excavations listed in Accounts 311.3, 311.4, 311.6, 311.7, 311.9 and 312.1 are calculated using the estimated percentages of the sum of the costs of Items 5.1, 5.2 and 5.3 of Ref. 7, table 28, listed in Appendix C, page 199, table XXX, escalated to mid-1978 dollars using the account specific escalation factors for Accounts 311. and 312., where appropriate, listed in table XXV.

(7) The separate balance-of-plant materials costs for the feedwater booster (2) and main feedwater (3) pumps are estimated from the combined balance-of-plant materials cost of these five pumps ($3,220,000), listed in Ref. 7, table 28, as follows: The combined equipment cost of the pumps $3,070,000 ((2)x($125,000) + (3)x($940,000)) is subtracted from the combined balance-of-plant materials cost and the remainder ($150,000) divided by the total horsepower of the five pumps (45,500 hp) resulting in $3.30/hp. This cost per horsepower is then multiplied by the horsepower of the two feedwater booster pumps, for example, to give $25,410 (7700 hp x $3.30/hp) and the equipment cost of the two pumps, $250,000, added to the product to give $275,410. This

NOTES TO TABLE XI (Concluded)

figure is then escalated to mid-1978 dollars ($341,500) using the 1.24 factor for FERC Account 312. listed in table XXV. Similarly the cost of the main feedwater pumps is estimated as $2,944,740 (i.e., ($3.30/hp)x(38,700 hp) + 3($940,000)), which is escalated to $3,651,500.

(8) The separate balance-of-plant materials costs for the stack gas reheat system forced draft fans and reheat air heaters are estimated from the combined $900,000 balance-of-plant materials cost listed in Ref. 7, table 28, as follows: The combined equipment cost of the fans and heaters, $810,000 (6 x $85,000 + 6 x $50,000), is subtracted from the combined balance-of-plant materials cost. The remainder, $90,000, is divided equally between the fans and heaters, and one $45,000 part is added to the equipment cost of the fans and the other to the equipment cost of the heaters to give $555,000 and $345,000 for the respective balance-of-plant materials costs of each. These values are escalated to mid-1978 dollars ($688,200 and $427,800, respectively) using the 1.24 factor for FERC Account 312. listed in table XXV.

(9) Includes the 20 percent contingency in Note 5 applied to the 15 percent A/E services and fee rate employed in the ECAS report (Ref. 7, page 44) to account for the change in the order of applying the contingency and A/E services and fee rates in this study compared to the ECAS study.

(10) Based on the guidelines specified by NASA for the ECAS study (Ref. 4).

(11) The sum of the Plant Capital Cost and Escalation and Interest During Construction divided by $(1.065)^{5.5}$ to de-escalate the Total Plant Capital Cost in Jan. 1984 at the completion of the 5.5 year construction period to mid-1978.

TABLE XII. - MODIFIED REFERENCE CONVENTIONAL FURNACE
COAL-FIRED POWER PLANT WITH WET SO_2 SCRUBBER
CAPITAL COST ESTIMATE DETAILS AS OF MID-1978
(250° F Stack Gas Reheat Temperature (1))
(Mid-1978 Dollars)

FERC Account Number	ECAS Report Ident. No(s). (2)	Account/Subdivision: Title	Account/Subdivision: Description/Specification	Material Costs (3): Major Component	Material Costs (3): Balance of Plant	Installation Cost (3)	Indirect Cost (4)	Contingency Allowance (5)	Total Cost
310.	-	LAND AND LAND RIGHTS	- - -			Not Included in Study			
311.	-	STRUCTURES AND IMPROVEMENTS (6)	Total Account 311.	-	13,155,560	12,304,700	11,077,954	7,307,643	43,845,857
311.1	7.0	Improvements to Site	Total Subdivision 311.1	-	1,647,200	3,530,170	3,178,656	1,671,205	10,027,231
311.11	7.1	Site Preparation and Improvements	Soil testing, clearing and grubbing, rough grading, finish grading, landscaping	-	11,600	1,185,810	1,067,734	453,029	2,718,172
311.12	7.2	Site Utilities	Storm and sanitary sewers, non-process service water	-	58,000	68,150	61,364	37,503	225,017
311.13	7.3	Roads and Railroads	Railroad spur, roads, walks and pa[illegible]g areas	-	858,400	368,010	331,366	311,555	1,869,331
311.14	7.4	Yard and Plant Fire Protection, Fences and Gates	- - -	-	696,000	708,760	638,186	408,589	2,451,535
311.15	7.5	Water Treatment Ponds	Earthwork, pond lining, off-site pipeline	-	23,200	1,199,440	1,080,006	460,529	2,763,176
311.3	-	Main (Turbine-Generator) Building	Total Subdivision 311.3	-	2,822,280	2,234,160	2,011,440	1,413,576	8,481,456
311.31	5.1,5.3	-	Excavation, substructure, dewatering and piling, including excavation and substructure for transmission plant switchyard	-	-	-	-	-	-
311.32	5.2	-	Building structure and services	-	-	-	-	-	-
311.4	-	Steam Gen[illegible]uilding	Total Subdivision 311.4	-	6,927,520	5,483,320	4,936,960	3,469,560	20,817,360
311.41	5.1,5.3	-	Excavation, substructure, dewatering and piling	-	-	-	-	-	-
311.42	5.2	-	Enclosure structure and services	-	-	-	-	-	-

*See page 100 for explanation of footnotes

TABLE XII. - (Continued)

FERC Account Number	ECAS Report Ident. No(s).(2)	Account/Subdivision Title	Account/Subdivision Description/Specification	Material Costs (3) Major Component	Material Costs (3) Balance of Plant	Installation Cost (3)	Indirect Cost (4)	Contingency Allowance (5)	Total Cost
311.6	-	Maintenance, Service, Warehouse and Office Building (Service Building)	Total Subdivision 311.6	-	962,800	762,120	685,560	482,096	2,892,576
311.61	5.1,5.3	-	Excavation, substructure, dewatering and piling	-	-	-	-	-	-
311.62	5.2	-	Building Structure and services	-	-	-	-	-	-
311.7	5.1,5.3	Other Buildings	Total Subdivision 311.7 Excavation and structure for makeup water intake	-	256,360	203,000	183,280	128,528	771,168
311.8	3.7	Cranes and Hoists	Total Subdivision 311.8 Crane and accessories in turbine hall	-	475,600	40,890	36,818	110,662	663,970
311.9	5.1,5.2	On-site Waste Treatment (Including Water Treatment) Building	Total Subdivision 311.9 Excavation, substructure building structure and services; lime, alum, ion exchange resin, acid, caustic and chlorine storage tanks; reagent metering and feeding pumps; mixers; clarifiers	-	63,800	51,040	45,240	32,016	192,036

*See page 100 for explanation of footnotes

TABLE XII. - (Continued)

FERC Account Number	ECAS Report Ident. No(s). (2)	Account/Subdivision		Material Costs (3)		Installation Cost (3)	Indirect Cost (4)	Contingency Allowance (5)	Total Cost
		Title	Description/Specification	Major Component	Balance of Plant				
312.	-	BOILER PLANT (3)	Total Account 312.	59,[illegible]	74,[illegible],3[illegible]0	33,689,56[illegible]	[illegible]4	39,446,055	237,276,329
312.1	8,5.1,.3	Coal Handling	Total Subdivision 312.1	-	8,914,36[illegible]	2,4[illegible]7,77[illegible]	2,169,231	2,[illegible]98,272	16,184,6[illegible]
			Coal, limestone and ash handling excavations, foundations pits and tunnels. Also, railcar dumping equipment, dust collectors, primary and secondary crushing equipment, belt scale, sampling station, magnetic cleaners, mobile equipment, coal silos, reclaiming feeders, and the following conveyors to coal pile and coal silos:						
312.11	-	Unloading and Yard Storage	- - -	-	-	-	-	-	-
	C-1	Coal Conveyor belt	60 in. wide, 340 ft. long, 3000 tph	-	-	-	-	-	-
	C-2	Coal Conveyor belt	60 in. wide, 760 ft. long, 3000 tph	-	-	-	-	-	-
	C-3	Coal Conveyor belt	60 in. wide, 190 ft. long, 3000 tph	-	-	-	-	-	-
312.12	-	Reclaim and Delivery	- - -	-	-	-	-	-	-
	C-4	Coal Conveyor belt	42 in. wide, 980 ft. long, 500 tph	-	-	-	-	-	-
	C-5	Coal Conveyor belt	42 in. wide, 540 ft. long, 500 tph	-	-	-	-	-	-
	C-6	Coal Conveyor belt	42 in. wide, 170 ft. long, 500 tph	-	-	-	-	-	-
	C-7	Coal Conveyor belt	42 in. wide, 110 ft. long, 500 tph	-	-	-	-	-	-
	C-8	Coal Conveyor belt (2 reqd.)	30 in. wide, 160 ft. long, 300 tph	-	-	-	-	-	-

*See page 100 for explanation of footnotes

TABLE XII. - (Continued)

FEPC Account Number	ECAS Report Ident. No(s). (2)	Account/Subdivision Title	Account/Subdivision Description/Specification	Material Costs (2) Major Component	Material Costs (2) Balance of Plant	Installation Cost (3)	Indirect Cost (4)	Contingency Allowance (5)	Total Cost
312.2	3.10	Slag and Ash Handling	Total Account 312.2	-	4,43[illegible]	888,770	6[illegible],271	1,225,648	7,353,[illegible]
			Bottom ash system, fly ash handling system for precipitators and air pre-heater, ash conveyors, railcar loading equipment, ash hoppers, sluice pumps and drives, piping, clinker grinder, pressure blowers, valves and piping, and the following storage silos and associated equipment:						
312.21	C-16	Fly ash storage silos (2 reqd.)	Feeders, unloaders and foundations, silos: total volume 833,184 cu. ft., 65 ft. high, 80 ft. dia.	-	-	-	-	-	-
312.3	3.9	Limestone Handling	Total Subdivision 312.3	-	1,550,000	320,540	288,622	431,832	2,590,995
			Magnetic cleaners, reclaiming feeders, belt scale, and the following conveyors to limestone pile and calciner:						
312.31	-	Conveyors		-	-	-	-	-	-
	C-9	Limestone Conveyor belt	60 in. wide, 500 ft. long, 3000 tph	-	-	-	-	-	-
	C-10	Limestone Conveyor belt	24 in. wide, 630 ft. long, 65 tph	-	-	-	-	-	-
	C-11	Limestone Conveyor belt	24 in. wide, 420 ft. long, 65 tph	-	-	-	-	-	-
	C-12	Limestone bucket Conveyor	24 in. wide, 120 ft. long, 100 tph	-	-	-	-	-	-
312.4	-	Steam Generator Equipment	Total Subdivision 312.4	49,265,200	16,591,200	18,314,490	16,490,834	20,132,345	120,794,070
312.41	1.1, Table 14	Steam Generator	Heat transfer surface and pressure parts; buckstays, braces and hangers; fuel-burning equipment, accessories, soot and ash equipment; control systems, brick-work, refractory and insulation; support steel & misc. materials; primary air fans & feedwater piping	49,265,200	8,432,000	12,238,800	11,020,128	16,191,226	97,147,354

*See page 100 for explanation of footnotes

TABLE XII. - (Continued)

FPC Account Number	ECAS Report Ident. No(s). (2)	Account/Subdivision Title	Description/Specification	Material Costs (3) Major Component	Material Costs (3) Balance of Plant	Installation Cost (3)	Indirect Cost (4)	Contingency Allowance (5)	Total Cost
312.42	6.7	Instrumentation and Controls	Integrated boiler controls boiler/ turbine coordinating controls, main mech. system control boards, sampling system includ. analyzers and sampling panel, stack emissions monitoring system, and data acquisition system	-	[illegible]	3,2[illegible]	[illegible]	[illegible]	[illegible]
312.43	1.2	Auxiliaries	Air preheater: flues and ducts to precipitators: insulation for flues and ducts; pulverizers, feeders and hoppers: and the following fans:	-	2,083,200	2,870,290	2,584,482	1,507,594	9,045,567
	F-9	Forced draft fans (2 reqd. @ $483,600 ea.)	Operating: 971,000 cfm @ 80° F, S.P. outlet=19 in. w.g. Test block: 1,165,000 cfm @ 105° F, S.P. outlet=24.7 in. w.g. Motor: 6,500 hp	-	-	-	-	-	-
	F-10	Primary air fans (2 reqd.)	Operating: 161,750 cfm @ 96° F, S.P. inlet = 19 in. w.g., S.P. outlet = 42 in. w.g. [illegible] cfm @ 121° F, S.P. inlet=19 in. w.g., [illegible] in. w.g. [illegible] 2,250 hp	Included in Subdivision 312.41)					
	F-14	Induced draft fans (4 reqd. @ $272,800 ea.)	Operating: 660,000 cfm @ 300° F, Total S.P. = 23 in. w.g. Test block: 800,000 cfm @ 325° F, Total S.P. = 30 in. w.g. Motor: 5,000 hp	-	-	-	-	-	-
312.5	-	Auxiliary Boiler System	Optional (not included)	-	-	-	-	-	-
312.6	-	Other Boiler Plant Systems	Total Subdivision 312.6	-	8,593,400	349,680	314,861	1,851,588	11,109,529
312.61	-	Condensate and Feedwater System	Total Subdivision 312.61	-	8,593,400	349,680	314,961	1,851,566	11,1[illegible]

*See page 100 for explanation of footnotes

TABLE XII. - (Continued)

Account Number	ECAS Report Ident. No's.(2)	Account/Subdivision Title	Description/Specification	Material Costs (3) Major Component	Material Costs (3) Balance of Plant	Installation Cost (3)	Indirect Cost (4)	Contingency Allowance(5)	Total Cost
	[illegible].3., F-4	Main condensate pumps & motors (2 reqd. @ $1[illegible],4[illegible] ea.)	Vertical centerline, 4250 gpm, 600 hp motor, 410 ft. TDH (Other pumps and drivers not listed elsewhere)	-	[illegible]	72,8[illegible]	[illegible]	188,8[illegible]	[illegible]
	[illegible].1., F-5 (7)	Feedwater booster pumps and motors (2 reqd. @ $355,000 ea.)	7,300 gpm, 3850hp, 1510 ft. TDH	-	341,500	29,140	26,238	79,375	476,254
	[illegible].1., F-6 (7)	Main boiler feed pumps and turbine drives (3 reqd. @ $1,165,600 ea.)	4900 gpm, 12,600 hp, 8300 ft. TDH	-	3,651,500	116,560	104,954	774,603	4,647,617
	F-2	Boiler feedwater piping	- - -	Included in Subdivision 314.41					
	[illegible].5., F-3	Feedwater heaters	Miscellaneous heaters and exchangers; tanks and vessels; and the following low pressure (4), intermediate pressure (1) and deaerating feedwater (1) heaters:	-	3,794,400	131,130	118,073	808,721	4,852,323

	Shell Press./Temp. psia/° F	Tube Press./Temp. psia/° F	Flow (100 Percent) lb/hr	Heat transfer area sq.ft.
LP#1	5/163	210/158	4.05×10^6	14,330
LP#2	11/195	210/190	4.05×10^6	13,550
LP#3	20/228	210/223	4.05×10^6	13,720
LP#4	67/300	210/295	4.05×10^6	18,770
IP	296/416	1040/415	6.22×10^6	45,660
HP	745/510	57[illegible]/519	6.22×10^6	49,700
DFH	6.22×10^6 lb/hr @ 353° F			

Account Number	ECAS Report Ident. No's.(2)	Account/Subdivision Title	Description/Specification	Material Costs (3) Major Component	Material Costs (3) Balance of Plant	Installation Cost (3)	Indirect Cost (4)	Contingency Allowance(5)	Total Cost
312.62	-	Water Treatment System	- - -	Included in Subdivision 311.9					
312.7	-	Effluent Control	Total Subdivision 312.7	10,000,000	6,051,200	3,540,510	3,187,967	4,555,935	27,335,612
312.71	1.3., F-11, Table 24 (M)	Precipitators and Breeching (4 reqd.)	Total Subdivision 312.71 Nominally 54 ft. high x 92 ft. wide x 44 ft. long ea. 1,262,000 lb. 1200 MW, 99.7 percent particulate removal efficiency, 695,000 acfm @ 300° F, including support steel	10,000,000	272,800	1,500,710	1,351,278	2,624,958	15,749,746

*See page 100 for explanation of footnotes

TABLE XII. - (Continued)

FERC Account Number	ECAS Report Ident. No(s).(2)	Account/Subdivision: Title	Account/Subdivision: Description/Specification	Material Costs (3): Major Component	Material Costs (3): Balance of Plant	Installation Cost (3)	Indirect Cost(4)	Contingency Allowance(5)	Total Cost
312.72	3.6, F-16	Chimney	Total Subdivision 312.72	-	1,946,800	1,646,410	1,482,47[illegible]	[illegible]	6,093,816
			Concrete stack and liner; lights and marker painting; hoists and platforms; stack foundation 40 ft. I.D., 500 ft. high						
312.73	-	Stack Gas Reheat System	Total Subdivision 312.73	-	3,831,600	393,390	354,219	915,842	5,495,051
	3.14, F-15 (8)	Forced draft fans for reheater air (6 reqd. @ $243,000 ea.)	Operating: 545,000 cfm @ 80° F, Total S.P. = 3.5 in. w.g. Test block: 654,000 cfm @ 105° F, Total S.P. = 4.55 in. w.g. Motor: 650 hp	-	1,618,200	189,410	170,550	395,632	2,373,792
	3.14, F-13 (8)	Stack gas reheat air heaters (6 reqd. @ $347,200 ea.)	4.5 ft. high, 21.5 ft. wide x 37.5 ft. long each	-	2,213,400	203,980	183,669	520,210	3,121,259
312.8	-	Flue Gas Desulfurization System	Total Subdivision 312.8	-	28,800,000	7,867,800	7,084,368	8,750,434	52,502,602
312.81	-	FGD Equipment	Total Subdivision 312.81	-	24,000,000	5,245,200	4,722,912	6,793,622	40,761,734
	3.15, F-12 (8)	Wet limestone SO_2 scrubbers (spray tower absorber) (6 reqd. @ $1,500,000 ea.)	Complete SO_2 scrubber vessels with pre-saturator and mist eliminator systems. Nominally 60 ft. high x 40 ft. wide x 18ft. long, 316L stainless steel, neoprene lined, 3 stages, 450,000 acfm @ 312° F each	-	10,560,000	1,253,020	1,128,251	2,588,254	15,529,525
	3.13	Scrubber ductwork	Flue gas duct outboard of electro-static precipitators, duct lining, duct insulation, dampers & expansion joints	-	4,054,800	3,015,990	2,715,674	1,957,293	11,743,757

*See pages 100 and 101 for explanation of footnotes

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TABLE XII. - (Continued)

FERC Account Number	ECAS Report Ident. No(s). (2)	Account/Subdivision: Title	Account/Subdivision: Description/Specification	Material Costs (3): Major Component	Material Costs (3): Balance of Plant	Installation Cost (3)	Indirect Cost (4)	Contingency Allowance (5)	Total Cost
	3.17	Scrubber system pumps	Slurry recycle (18 @ $53,500 ea.); mist eliminator wash (3 @ $33,000 ea.); slurry storage and transfer (4 @ $5,500 ea.); slurry feed (3 @ $[illegible],000 ea.); pond feed tank (3 @ $13,[illegible] ea.); pond feed booster (2 @ $20,000 ea.); pond water recycle and booster (4 @ $10,500 ea.)	-	1,812,080	145,700	131,192	417,778	2,506,670
	3.18	Scrubber system tanks	Tanks and agitators for absorber effluent hold, pond feed, entrainment separator surge, slurry surge, slurry storage and slurry transfer	-	3,360,000	58,280	52,477	694,151	4,164,908
	6.2 (M)	Scrubber system large piping	Makeup water, re-saturation slurry water, mist eliminator wash, absorber slurry effluent tank overflow, pond feed, pond recycle water, limestone slurry, recycle slurry, air heater steam, supply, and air heater condensate return piping	-	4,213,200	772,210	695,318	1,136,146	6,816,874
312.82	5.5	Foundations and Structural	Total Subdivision 312.82 Foundations earthwork and structures particular to scrubber equipment	-	4,800,000	2,622,600	2,361,456	1,956,811	11,740,867
312.83	3.16, (M)	Lime Manufacturing System	Total Subdivision 312.83	-	Deleted from modified plant				
	-	Limestone handling system excavations, foundations, conveyors, etc.	- - -	Included in Subdivisions 312.1 & 312.3					

*See page 100 for explanation of footnotes

TABLE XII. - (Continued)

FERC Account Number	ECAS Report Ident. No(s).(2)	Account/Subdivision		Material Costs (3)		Installation Cost (3)	Indirect Cost (4)	Contingency Allowance (5)	Total Cost
		Title	Description/Specification	Major Component	Balance of Plant				
314.	-	STEAM TURBINE - GENERATOR AND AUXILIARIES	Total Account 314.	33,020,000	24,841,200	18,772,505	16,903,243	18,707,390	112,244,337
314.1	2.0, Table 14, Fig.5 Table 24	Steam Turbine and Auxiliaries	Total Subdivision 314.1	33,020,000	127,000	1,790,700	1,612,392	7,310,018	43,860,110
			820 MW_e guaranteed generator output; tandem compound 4 flow turbine with 33.5 in. last stage buckets; 2.3" Hg abs 3500 psig/1000° F throttle steam, 1000° F/675 psig reheat steam, 15.4 percent continuous extraction for stack gas reheat; exciter 992 MVA generator @ 75 psig hydrogen pressure; 0.9 pf. Hydrogen, lube oil and seal oil systems, stop-throttle valves, cross-over piping, insulation motors for auxiliaries.						
314.2	3.4, F-1	Condenser & Auxiliaries	Total Subdivision 314.2	-	2,692,400	[illegible]38,760	214,986	629,229	3,775,375
			Shells, tubes, air ejectors at 2.3 in. Hg (abs.), 3.31 x 10^5 sq.ft. of heat transfer area, 3.93x10^6 pph						
314.3	-	Circulating Water System	Total Subdivision 314.3	-	5,473,700	2,163,763	1,948,307	1,917,154	11,502,923
314.31	-	Pumps, Valves, Piping and Structure	Total Subdivision 413.31	-	889,000	44,768	40,310	194,815	1,168,893
	3.2, F-7	Circulating water pumps and motors (3 @ $279,400)	82,000 gpm, 2250 hp, 75ft. TDH each	-	889,000	44,768	40,310	194,815	1,168,893
	5.4	Circulating water valves, piping & structure	- - -	Included in Subdivision 314.32					
314.32	-	Cooling Towers	Total Subdivision 314.32	-	4,584,700	2,118,995	1,907,997	1,722,338	10,334,031
	3.11, F-8	Tower Structure (20 cells)	Mechanical draft towers with fans and motors	-	2,832,100	775,970	698,703	861,355	5,168,128
	5.4,	Tower basin & circu-	Circulating water pump pads, riser and concrete envelope for pipe; cooling tower basin; circulating water pipe (I.D.= 114 in.) & valves: misc. steel & fire protection. 246,000 gpm	-	1,752,600	1,343,025	1,209,294	860,99[illegible]	5,165,903

*See page 100 for explanation of footnotes

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TABLE XII. - (Continued)

FERC Account Number	ECAS Report Ident. No(s).(2)	Account/Subdivision		Material Costs (1)		Installation Cost (3)	Indirect Cost (4)	Contingency Allowance (5)	Total Cost
		Title	Description/Specification	Major Component	Balance of Plant				
314.4	-	Steam Piping Systems	Total Subdivision 314.4	-	14,439,900	14,131,608	12,724,460	8,259,194	49,555,161
314.41	6.1, F-2	Main Steam	Total Subdivision 314.41 Main steam (I.D.=15.3 in., t_m=3.97 in.); hot reheat (I.D.=18.1 in., t_m=2.25 in.); cold reheat I.D.= 32.54 in., t_m=1.57 in.); feedwater (I.D.=26.54 in., 0.675 in.) and condensate large piping, valves and fittings.	-	4,889,500	1,208,723	1,088,365	1,437,317	8,623,935
314.42	6.3	Auxiliary Steam	- - -	Included in Subdivision 314.43					
314.43	-	Miscellaneous Piping Systems	Total Subdivision 314.43	-	9,550,400	12,922,886	11,636,096	6,821,876	40,931,257
	6.3	Other large piping	Auxiliary steam, process water, auxiliary systems	-	5,143,500	3,447,098	3,103,855	2,338,890	14,033,343
	6.4	Small piping	All piping, valves and fittings of 2 in. diameter and less	-	1,714,500	2,268,220	2,042,363	1,205,017	7,230,100
	6.5	Hangers and miscellaneous labor operations	All hangers and supports; material handling; scaffolding; and associated miscellaneous labor operations	-	1,854,200	6,267,450	5,643,372	2,753,004	16,518,026
	6.6	Pipe insulation	- - -	-	838,200	940,118	846,506	524,965	3,149,788
314.5	3.12	Other Turbine Plant & Mechanical Equipment	Total Subdivision 314.5 Water treatment & chemical injection, air compressors & auxiliaries; fuel oil handling system, ignition & warmup; screenwell; misc. plant equipment & motors, & equipment insul.	-	2,108,200	447,675	403,098	591,795	3,550,768

*See page 100 for explanation of footnotes

TABLE XII - (Continued)

FERC Account Number	ECAS Report Item No(s) (2)	Account/Subdivision: Title	Account/Subdivision: Description/Specification	Material Costs (3): Major Component	Material Costs (3): Balance of Plant	Installation Cost (3)	Indirect Cost (4)	Contingency Allowance (5)	Total Cost
[illegible]	-	ACCESSORY ELECTRIC EQUIPMENT	Total Account 315.		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
315.1	4-2	Station and Auxiliary Transformers	Total Subdivision 315.1	-	[illegible]	[illegible]	221,228	408,264	2,449,584
			Station service and startup transformers; service transformers for boiler and scrubber systems; generator main bus as follows:						
	E-2	Unit Auxiliary Transformers (2 reqd.)	40/54/67 MVA, 65° C, OA/FA/FOA, 24/13.8 kV, 3-phase, 60Hz	-	-	-	-	-	-
	E-4	Startup Transformer	28/37.5/47 MVA, OA/FA/FOA, 500/13.8 kV, 65° C, 3-phase, 60Hz	-	-	-	-	-	-
	E-6	Boiler Auxiliary Transformers (2 reqd.)	5500 kVA, OA, 65° C, 13.8/4.16 kV, 3-phase, 60Hz	-	-	-	-	-	-
	E-8	Scrubber Transformers (2 reqd.)	5000 kVA, OA, 65° C, 13.8/4.16 kV, 3-phase, 60 Hz	-	-	-	-	-	-
315.2	-	Miscellaneous Motors	- - -	Included in Subdivision 314.5					
315.3	4.3	Switchgear & Motor Control Centers	Total Subdivision 315.3	-	4,182,000	607,005	546,563	1,067,114	6,402,681
			Switchgear, switchyard & load centers; motor control centers; local control stations; distribution panels, relay & meter boards; & the following transformers:						
	E-5	Misc. 480 V load control center transformers (14 reqd.)	1689 kVA, OA, 65° C, 13.8kV/480 - 277 V, 3-phase, 60Hz	-	-	-	-	-	-
	E-7	Local control center transformers (2 reqd.)	7000 kVA, OA, 65° C, 13.8/4.16 kV, 3-phase, 60Hz	-	-	-	-	-	-
315.4	4.6	[illegible] Cable and Bus- [illegible] Cable	Total Subdivision 315.4	-	5,018,400	9,133,980	8,224,469	4,475,370	26,852,219

*See page 100 for explanation of footnotes

TABLE XII. - (Concluded)

FERC Account Number	ECAS Report Ident. No(s). (2)	Account/Subdivision: Title	Account/Subdivision: Description/Specification	Material Costs (3): Major Component	Material Costs (3): Balance of Plant	Installation Cost (3)	Indirect Cost (4)	Contingency Allowance (5)	Total Cost
315.5	4.4	Miscellaneous Electrical Equipment	Total Subdivision 315.5	-	2,472,300	5,246,259	4,723,864	2,488,484	14,930,9[illegible]
			Communications; grounding; cathodic & freeze protection; lighting; pre-operational testing						
315.6	-	Integrated Control System	- - -	Included in Subdivision 312.42					
315.7	-	Data Acquisition System	- - -	Included in Subdivision 312.42					
315.8	4.5, E-3	Emergency Power System	Total Subdivision 315.8	-	135,300	28,905	26,027	38,045	228,278
			Diesel generator, batteries & associated d.c. equipment. 1000 KW, 3-phase, 60 Hz, 480 V, 0.8 pf.						
316.	-	MISCELLANEOUS POWER PLANT EQUIPMENT	Total Account 316.	-	350,000	14,688	13,225	75,583	453,495
316.1	-	Fuel Oil Handling System	- - -	Included in Subdivision 314.5					
316.2	-	Fire Protection System	- - -	Included in Subdivision 311.14					
316.3	7.6	Machine & Maintenance Shops	- - -	-	350,000	14,688	13,225	75,583	453,395
350.	-	TRANSMISSION PLANT	Total Account 350.	-	2,323,000	54,050	48,668	485,144	2,910,862
350.1	5.1, 5.2, 5.3	Structures & Improvements	- - -	Included in Subdivision 311.3					
350.2	4.1, E-1	Main Transformers	Total Subdivision 350.2 468MVA, FOA, 65° C, 24/500kV	-	2,323,000	54,050	48,668	485,144	2,910,862
350.3	4.3	Switchyard	- - -	Included in Subdivision 315.3					
		Total of Direct Accounts 310. to 350.		92,235,200	128,991,520	80,097,343	72,121,394	74,699,091	448,154,548
		A/E Services & Fee @ 18 percent of Balance of Plant Materials, Installation & Indirect Costs (9)							50,617,846
		Plant Capital Cost							498,812,394
		Escalation & Interest During Construction @ 54.8 percent (5.5 yr. Constr. per. 6.5 percent escalation rate, 10 percent interest rate) (10)							273,349,192
		Total Plant Capital Cost in Jan. 1984 Dollars							772,161,586
		Total Plant Capital Cost De-Escalated to mid-1978 (11)							546,116,565

*See pages 100 and 101 for explanation of footnotes

NOTES TO TABLE XII

(1) Based on ECAS report tables 15 and 16 (Ref. 7).

(2) Identification numbers consisting of letters and numerals refer to table 15 of the ECAS report, reproduced in Appendix C, pages 178 to 180, for reference. Identification numbers consisting of numerals only refer to table 16 of the ECAS report, reproduced in Appendix C pages 181 to 187, for reference. References to other ECAS report tables are as indicated. The letter (M) following an identification number(s) indicates that the description/specification of the item in that subdivision is modified relative to that in the ECAS reference plant (see also table V).

(3) Escalated from the mid-1975 value listed in table XXXII using the account specific escalation factor listed in table XXV except for the major component and balance-of-plant costs in FERC Account Subdivisions 312.7 and 312.8, which were determined from a manufacturer's verbal budget cost estimate.

(4) See Note 3.

(5) Based on the 20 percent contingency rate included in the ECAS report (Ref. 7, page 44).

(6) The costs of the buildings, structures and excavations listed in Accounts 311.3, 311.4, 311.6, 311.7, 311.9 and 312.1 are calculated using the estimated percentages of the sum of the costs of Items 5.1, 5.2 and 5.3 of Ref. 7, table 16 listed in Appendix C, page 199, table XXX, escalated to mid-1978 dollars using the account specific factors for Accounts 311. and 312., where appropriate, listed in table XXV. Note that the same table applies to both the 250° and 175° F (394° and 353° K) reheat cases.

(7) The separate balance-of-plant materials costs for the feedwater booster (2) and main feedwater (3) pumps are estimated from the combined balance-of-plant materials cost of these five pumps ($3,220,000), listed in Ref. 7, table 16, as follows: The combined equipment cost of the pumps $3,070,000 ((2) ($125,000) + (3) ($940,000)) is subtracted from the combined balance-of-plant

NOTES TO TABLE XII (Concluded)

materials cost and the remainder ($150,000) divided by the total horsepower of the five pumps (45,500 hp) resulting in $3.30/hp. This cost per horsepower is then multiplied by the horsepower of the two feedwater booster pumps, for example, to give $25,410 (7700 hp x $3.30/hp) and the equipment cost of the two pumps, $250,000, added to the product to give $275,410. This figure is then escalated to mid-1978 dollars ($341,500) using the 1.24 factor for FERC Account 312. listed in table XXV. Similarly the cost of the main feedwater pumps is estimated as $2,944,740 (i.e., ($3.30/hp) x (38,700 hp) + 3($940,000)), which is escalated to $3,651,500.

(8) The separate balance-of-plant materials costs for the stack gas reheat system forced draft fans and reheat air heaters are estimated from the combined $3,090,000 balance-of-plant materials cost listed in Ref. 7, table 16, as follows: The combined equipment cost of the fans and heaters, $2,880,000 (6x$200,000 + 6x$280,000), is subtracted from the combined balance-of-plant materials cost. The remainder, $210,000, is divided equally between the fans and heaters, and one $105,000 part is added to the equipment cost of the fans and the other to the equipment cost of the heaters to give $1,305,000 and $1,785,000 for the respective balance-of-plant materials costs of each. These values are escalated to mid-1978 dollars ($1,618,200 and $2,213,400, respectively) using the 1.24 factor for FERC Account 312. listed in table XXV.

(9) Includes the 20 percent contingency in Note 5 applied to the 15 percent A/E services and fee rate employed in the ECAS report (Ref. 7, page 44) to account for the change in the order of applying the contingency and A/E services and fee rates in this study compared to the ECAS study.

(10) Based on the guidelines specified by NASA for the ECAS study (Ref. 4).

(11) The sum of the Plant Capital Cost and Escalation and Interest During Construction divided by $(1.065)^{5.5}$ to de-escalate the Total Plant Capital Cost in Jan. 1984 at the completion of the 5.5 year construction period to mid-1978.

TABLE XIII. - MODIFIED REFERENCE CONVENTIONAL FURNACE COAL-FIRED POWER PLANT WITH WET SO_2 SCRUBBER CAPITAL COST ESTIMATE DETAILS AS OF MID-1978
(175° F Stack Gas Reheat Temperature (1))
(Mid-1978 Dollars)

FERC Account Number	ECAS Report Ident. No(s). (2)	Account/Subdivision		Material Costs (3)		Installation Cost (3)	Indirect Cost (4)	Contingency Allowance (5)	Total Cost
		Title	Description/Specification	Major Component	Balance of Plant				
310.	-	LAND AND LAND RIGHTS	- - -			Not Included in Study			
311.	-	STRUCTURES AND IMPROVEMENTS (6)	Total Account 311.	-	13,155,560	12,304,700	11,077,954	7,307,643	43,845,857
311.1	7.0	Improvements to Site	Total Subdivision 311.1	-	1,647,200	3,530,170	3,178,655	1,671,205	10,027,230
311.11	7.1	Site Preparation and Improvements	Soil testing, clearing and grubbing, rough grading, finish grading, landscaping	-	11,600	1,185,810	1,067,734	453,029	2,718,172
311.12	7.2	Site Utilities	Storm and sanitary sewers, non-process service water	-	58,000	68,150	61,364	37,503	225,017
311.13	7.3	Roads and Railroads	Railroad spur, roads, walks and parking areas	-	858,400	368,010	331,366	311,555	1,869,331
311.14	7.4	Yard and Plant Fire Protection, Fences and Gates	- - -	-	696,000	708,760	638,186	408,589	2,451,535
311.15	7.5	Water Treatment Ponds	Earthwork, pond lining, off-site pipeline	-	23,200	1,199,440	1,080,006	460,529	2,763,176
311.3	-	Main (Turbine-Generator) Building	Total Subdivision 311.3	-	2,822,280	2,234,160	2,011,440	1,413,576	8,481,456
311.31	5.1,5.3	-	Excavation, substructure, de-watering and piling, including excavation and substructure for transmission plant switch-yard	-	-	-	-	-	-
311.32	5.2	-	Building structure and services	-	-	-	-	-	-
311.4	-	Steam Generator Building	Total Subdivision 311.4	-	6,927,520	5,483,320	4,936,960	3,469,560	20,817,360
311.41	5.1,5.3	-	Excavation, substructure, de-watering and piling	-	-	-	-	-	-
311.42	5.2	-	Enclosure structure and services	-	-	-	-	-	-

*See page 116 for explanation of footnotes

TABLE XIII. - (Continued)

FERC Account Number	ECAS Report Ident. No(s).(2)	Account/Subdivision Title	Account/Subdivision Description/Specification	Material Costs (3) Major Component	Material Costs (3) Balance of Plant	Installation Cost (3)	Indirect Cost (4)	Contingency Allowance(5)	Total Cost
311.6	-	Maintenance, Service, Warehouse and Office Building (Service Building)	Total Subdivision 311.6	-	962,800	762,120	685,560	482,096	2,8[illegible],576
311.61	5.1,5.3	-	Excavation, substructure, dewatering and piling	-	-	-	-	-	
311.62	5.2	-	Building Structure and services	-	-	-	-	-	-
311.7	5.1,5.3	Other Buildings	Total Subdivision 311.7 Excavation and structure for makeup water intake	-	256,360	203,000	183,280	128,528	771,168
311.8	3.7	Cranes and Hoists	Total Subdivision 311.8 Crane and accessories in turbine hall	-	475,600	40,890	36,818	110,662	663,970
311.9	5.1,5.2	On-site Waste Treatment (Including Water Treatment) Building	Total Subdivision 311.9 Excavation, substructure building structure and services; lime, alum, ion exchange resin, acid, caustic and chlorine storage tanks; reagent metering and feeding pumps; mixers; clarifiers	-	63,800	51,040	45,240	32,016	192,096

*See page 116 for explanation of footnotes

TABLE XIII. - (Continued)

FPC Account Number	ECAS Report Ident. No(s). (2)	Account/Subdivision Title	Description/Specification	Material Costs (3) Major Component	Balance of Plant	Installation Cost (3)	Indirect Cost (4)	Contingency Allowance (5)	Total Cost
312.	-	BOILER PLANT (3)	Total Account 312.	59,265,200	69,934,160	31,693,470	28,538,823	37,886,331	227,317,964
312.1	2.8, 5.1, 5.3	Coal Handling	Total Subdivision 312.1	-	8,914,360	2,407,770	2,169,231	2,698,272	16,189,633
			Coal, limestone and ash handling excavations, foundations pits and tunnels. Also, railcar dumping equipment, dust collectors, primary and secondary crushing equipment, belt scale, sampling station, magnetic cleaners, mobile equipment, coal silos, reclaiming feeders, and the following conveyors to coal pile and coal silos:						
312.11	-	Unloading and Yard Storage	- - -	-	-	-	-	-	-
	C-1	Coal Conveyor belt	60 in. wide, 340 ft. long, 3000 tph	-	-	-	-	-	-
	C-2	Coal Conveyor belt	60 in. wide, 760 ft. long, 3000 tph	-	-	-	-	-	-
	C-3	Coal Conveyor belt	60 in. wide, 190 ft. long, 3000 tph	-	-	-	-	-	-
312.12	-	Reclaim and Delivery	- - -	-	-	-	-	-	-
	C-4	Coal Conveyor belt	42 in. wide, 980 ft. long, 500 tph	-	-	-	-	-	-
	C-5	Coal Conveyor belt	42 in. wide, 540 ft. long, 500 tph	-	-	-	-	-	-
	C-6	Coal Conveyor belt	42 in. wide, 170 ft. long, 500 tph	-	-	-	-	-	-
	C-7	Coal Conveyor belt	42 in. wide, 110 ft. long, 500 tph	-	-	-	-	-	-
	C-8	Coal Conveyor belt (2 reqd.)	30 in. wide, 160 ft. long, 300 tph	-	-	-	-	-	-

*See page 116 for explanation of footnotes

TABLE XIII. - (Continued)

FERC Account Number	ECAS Report Ident. No(s).(2)	Account/Subdivision		Material Costs (3)		Installation Cost (3)	Indirect Cost (4)	Contingency Allowance(5)	Total Cost
		Title	Description/Specification	Major Component	Balance of Plant				
312.2	3.10	Slag and Ash Handling	Total Account 312.2	-	4,439,200	888,770	800,271	1,225,648	7,353,889
			Bottom ash system, fly ash handling system for precipitators and air preheater, ash conveyors, railcar loading equipment, ash hoppers, sluice pumps and drives, piping, clinker grinder, pressure blowers, valves and piping, and the following storage silos and associated equipment:						
312.21	C-15	Fly ash storage silos (2 reqd.)	Feeders, unloaders and foundations, silos: total volume 833,184 cu. ft., 85 ft. high, 80 ft. dia.	-	-	-	-	-	-
312.3	3.9	Limestone Handling	Total Subdivision 312.3	-	1,550,000	320,540	288,622	431,832	2,590,995
			Magnetic cleaners, reclaiming feeders, belt scale, and the following conveyors to limestone pile and calciner:						
312.31	-	Conveyors		-	-	-	-	-	-
	C-9	Limestone Conveyor belt	60 in. wide, 500 ft. long, 3000 tph	-	-	-	-	-	-
	C-10	Limestone Conveyor belt	24 in. wide, 630 ft. long, 65 tph	-	-	-	-	-	-
	C-11	Limestone Conveyor belt	24 in. wide, 420 ft. long, 65 tph	-	-	-	-	-	-
	C-12	Limestone bucket Conveyor	24 in. wide, 120 ft. long, 100 tph	-	-	-	-	-	-
312.4	-	Steam Generator Equipment	Total Subdivision 312.4	49,265,200	16,492,000	18,299,920	16,477,715	20,106,967	120,641,802
312.41	1.1, Table 14	Steam Generator	Heat transfer surface and pressure parts; buckstays, braces and hangers; fuel-burning equipment, accessories, soot and ash equipment; control systems, brickwork, refractory and insulation; support steel & misc. materials; primary air fans & feedwater piping	49,265,200	8,432,000	12,238,800	11,020,128	16,191,226	97,147,354

*See page 116 for explanation of footnotes

TABLE XIII. - (Continued)

FERC Account Number	ECAS Report Ident. No(s). (2)	Account/Subdivision Title	Description/Specification	Material Costs (1) Major Component	Balance of Plant	Installation Cost (3)	Indirect Cost (4)	Contingency Allowance (5)	Total Cost
312.42	6.7	Instrumentation and Controls	Integrated boiler controls, boiler/ turbine coordinating controls, main mech. system control boards, sampling system includ. analyzers and sampling panel, stack emissions monitoring system and data acquisition system	-	5,976,800	3,190,830	2,873,105	2,408,147	14,448,882
312.43	1.2	Auxiliaries	Air preheater; flues and ducts to precipitators; insulation for flues and ducts; pulverizers, feeders and hoppers; and the following fans:	-	2,083,200	2,870,290	2,584,482	1,507,594	9,045,567
	P-9	Forced draft fans (2 reqd. @ $483,600 ea.)	Operating: 971,000 cfm @ 80° F, S.P. outlet = 19 in.w.g. Test block: 1,165,000 cfm @ 105° F, S.P. outlet = 27.4 in. w.g. Motor: 6,500 hp	-	-	-	-	-	-
	P-10	Primary air fans (2 reqd.)	Operating: 161,750 cfm @ 96° F, S.P. inlet = 19 in. w.g., S.P. outlet = 42 in. w.g. Test Block: 194,000 cfm @ 121° F, S.P. inlet = 19 in. w.g., S.P. outlet=54.6 in. w.g. Motor: 2,250 hp		(Included in Subdivision 312.41)				
	P-14	Induced draft fans (4 reqd. @ $272,800 ea.)	Operating: 660,000 cfm @ 300° F, Total S.P. = 23 in. w.g. Test block: 800,000 cfm @ 325° F, Total S.P. = 30 in. w.g. Motor: 5,000 hp	-	-	-	-	-	-

*See page 116 for explanation of footnotes

TABLE XIII. - (Continued)

FERC Account Number	ECAS Report Ident. No(s), (2)	Account/Subdivision: Title	Account/Subdivision: Description/Specification	Material Costs (3): Major Component	Material Costs (3): Balance of Plant	Installation Cost (3)	Indirect Cost (4)	Contingency Allowance (5)	Total Cost
312.5	-	Auxiliary Boiler System	Optional (not included)	-	-	-	-	-	-
312.6	-	Other Boiler Plant Systems	Total Subdivision 312.6	-	8,742,200	349,680	314,861	1,881,349	11,288,089
312.61	-	Condensate and Feedwater System	Total Subdivision 312.61	-	8,742,200	349,680	314,861	1,881,349	11,288,089
	3.3, F-4	Main condensate pumps & motors (2 reqd. @ $117,800 ea.)	Vertical centerline, 5100 gpm, 750 hp motor, 410 ft. TDH (Other pumps and drivers not listed elsewhere)	-	830,800	72,850	65,596	193,849	1,163,095
	3.1, F-5 (7)	Feedwater booster pumps and motors (2 reqd. @ $155,000 ea.)	7,300 gpm, 3850hp, 1510 ft. TDH	-	341,500	29,140	26,238	79,376	476,254
	3.1, F-6 (7)	Main boiler feed pumps and turbine drives (3 reqd. @ $1,165,600 ea.)	4900 gpm, 12,600 hp, 8300 ft. TDH	-	3,651,500	116,560	104,954	774,603	4,646,617
	F-2	Boiler feedwater piping	- - -	Included in Subdivision 314.41					
	3.5, F-3	Feedwater heaters	Miscellaneous heaters and exchangers; tanks and vessels; and the following low pressure (4), intermediate pressure (1) and deaerating feedwater (1) heaters:	-	3,918,400	131,130	118,073	833,521	5,001,123

	Shell Press./Temp. psia/°F	Tube Press./Temp. psia/°F	Flow 100 percent lb/hr	Heat transfer area sq.ft.
LP#1	5/163	210/158	4.75×10^6	17,170
LP#2	11/195	210/190	4.75×10^6	16,260
LP#3	20/228	210/223	4.75×10^6	16,600
LP#4	67/300	210/295	4.75×10^6	22,710
IP	296/416	1040/415	6.22×10^6	45,660
HP	745/510	5700/519	6.22×10^6	49,700
DFH	6.22×10^6 lb/hr @ 353° F			

FERC Account Number	ECAS Report Ident. No(s), (2)	Title	Description/Specification	Major Component	Balance of Plant	Installation Cost (3)	Indirect Cost (4)	Contingency Allowance (5)	Total Cost
312.62	-	Water Treatment System	- - -	Included in Subdivision 311.9					
312.7	-	Effluent Control	Total Subdivision 312.7	10,000,000	2,926,400	2,855,720	2,571,363	3,670,697	22,024,180

*See page 116 for explanation of footnotes

TABLE XIII. - (Continued)

FERC Account Number	ECAS Report Ident. No(s). (2)	Account/Subdivision		Material Costs (3)		Installation Cost (3)	Indirect Cost (4)	Contingency Allowance (5)	Total Cost
		Title	Description/Specification	Major Component	Balance of Plant				
312.71	1.3, F-11, Table 14 [illegible]	Precipitators and Breeching (4 reqd.)	Total Subdivision 312.71	10,000,000	272,800	1,500,710	1,351,278	2,624,958	15,749,746
			Nominally 54 ft. high x 92 ft. wide x 44 ft. long each, 1,262,000 lb., 1296 kVA, 99.7 percent particulate removal efficiency, 595,000 acfm @ 300° F, including support steel						
312.72	3.6, F-16	Chimney	Total Subdivision 312.72	-	1,537,600	1,253,020	1,128,251	783,774	4,702,645
			Concrete stack and liner; lights and marker painting; hoists and platforms; stack foundation 27 ft. I.D., 500 ft. high						
312.73	-	Stack Gas Reheat System	Total Subdivision 312.73	-	1,116,000	101,990	91,834	261,965	1,571,789
	3.14, F-15 (8)	Forced draft fans for reheater air (6 reqd. @ $[illegible] ea.)	Operating: 123,000 cfm @ 80°F, Total S.P. = 3.5 in. w.g. Test block: 147,000 cfm @ 105°F, Total S.P. = 4.55 in. w.g. Motor: 150 hp	-	688,200	43,710	39,358	154,254	925,521
	3.14, F-13 (8)	Stack gas reheat air heaters (6 required @ $[illegible] ea.)	2.5 ft. high, 18.2 ft. wide x 10.7 ft. long each	-	427,800	58,280	52,477	107,711	646,268

*See pages 116 and 117 for explanation of footnotes

TABLE XIII. - (Continued)

FPPC Account Number	ECAS Report Ident. No(s).(2)	Account/Subdivision: Title	Account/Subdivision: Description/Specification	Material Costs (3): Major Component	Material Costs (3): Balance of Plant	Installation Cost (3)	Indirect Cost(4)	Contingency Allowance(5)	Total Cost
312.8	-	Flue Gas Desulfurization System	Total Subdivision 312.8	-	20,870,000	6,571,070	5,016,750	7,871,566	47,229,395
312.81	-	FGD Equipment	Total Subdivision 312.81	-	22,670,000	3,948,470	3,555,393	5,014,755	35,4[illegible]
	3.15, F-12 (**)	Wet limestone SO_2 scrubbers (spray tower absorber) (6 reqd. @ $1,[illegible],000 ea.)	Complete SO_2 scrubber vessels with pre-saturator and mist eliminator systems. Nominally 60 ft. high x 40 ft. wide x 18 ft. long, 316L stainless steel, neoprene lined, 3 stages, 450,000 acfm @ 312° F each.	-	10,560,000	1,253,120	1,128,231	2,588,254	15,529,525
	3.13 (**)	Scrubber ductwork	Flue gas duct outboard of electrostatic precipitators, duct lining, duct insulation, dampers & expansion joints	-	2,418,000	1,748,400	1,574,304	1.148,141	6,888,845
	3.17 (**)	Scrubber system pumps	Slurry recycle (18 @ $33,500 ea.); mist eliminator wash (3 @ $12,000 ea.); slurry storage and transfer (4 @ $5,500 ea.); slurry feed (3 @ $7,000 ea.); pond feed tank (3 @ $13,000 ea.); pond feed booster (2 @ $20,000 ea.); pond water recycle and booster (4 @ $16,500 ea.)	-	1,812,000	145,700	131,192	417,778	2,506,670
	3.18 (**)	Scrubber system tanks	Tanks and agitators for absorber effluent hold, pond feed, entrainment separator surge, slurry surge, slurry storage and slurry transfer	-	3,360,000	58,280	52,477	694,151	4,164,908

*See page 116 for explanation of footnotes

TABLE XIII. - (Continued)

FEPC Account Number	ECAS Report Ident. No(s). (2)	Account/Subdivision: Title	Account/Subdivision: Description/Specification	Material Costs (3): Major Component	Material Costs (3): Balance of Plant	Installation Cost (3)	Indirect Cost(4)	Contingency Allowance(5)	Total Cost
	6.2	Scrubber system large piping	Makeup water, re-saturation slurry water, mist eliminator wash, absorber slurry effluent tank overflow, pond feed, pond recycle water, limestone slurry, recycle slurry, air heater steam, supply, and air heater condensate return piping	-	3,920,000	743,070	669,079	1,066,430	6,398,579
312.82	5.5 (1)	Foundations and Structural	Total Subdivision 312.82	-	4,800,000	2,622,600	2,361,456	1,958,811	11,743,867
			Foundations earth-work and structures particular to scrubber equipment						
312.83	3.16, C-13, (4) C-14, C-15	Lime Manufacturing System	Total Subdivision 312.83	-	Deleted from modified plant				
			Limestone calciner: 650tons/day, nominal (880 tons/day, design), 12 ft. wide x 48ft. long traveling grate, 13ft. I.D. x 180ft. long rotary kiln with Niems-type cooler, coal conveyor, bucket elevator and storage bin, coal grinding/firing equipment, control panel/instrumentation, refractories, drives, induced draft fan, baghouse dust collector and ducting, kiln stack, lime conveyor bucket elevator, storage silos and lime slaker						
	-	Limestone handling system excavations, foundations, conveyors, etc.	- - -	Included in Subdivisions 312.1 & 312.3					

*See page 116 for explanation of footnotes

TABLE XIII. - (Continued)

FERC Account Number	ECAS Report Ident. No(s).(2)	Account/Subdivision: Title	Account/Subdivision: Description/Specification	Material Costs (3): Major Component	Material Costs (3): Balance of Plant	Installation Cost (3)	Indirect Cost (4)	Contingency Allowance (5)	Total Cost
314.	-	STEAM TURBINE - GENERATOR AND AUXILIARIES	Total Account 314.	33,972,500	26,060,400	19,100,800	17,198,848	19,266,510	115,599,058
314.1	2.0, Fig., 5 Table 24	Steam Turbine and Auxiliaries	Total Subdivision 314.1	33,972,500	127,000	1,790,700	1,612,392	7,530,518	45,033,110
			869 MWe guaranteed generator output, tandem compound 4 flow turbine with 33.5 in. last stage bycjets 2.3" Hg abs; 3500 psig/1000° F throttle steam, 1000° F/675 psig reheat steam; 3.5 percent continuous extraction for stack gas reheat exciter, 992 MVA generator @ 75 psig hydrogen pressure; 0.9 pf. Hydrogen, lube oil and seal oil systems, stopthrottle valves, cross-over piping, insulation motors for auxiliaries.						
314.2	3.4, F-1	Condenser & Auxiliaries	Total Subdivision 314.2	-	3,098,800	253,683	228,422	716,181	4,297,086
			Shells, tubes, air ejectors at 2.3 in. Hg (abs.), 3.97×10^5 sq.ft. of heat transfer area, 4.67×10^6 pph						
314.3	-	Circulating Water System	Total Subdivision 314.3	-	6,362,700	2,506,980	2,257,349	2,225,406	13,352,435
314.31	-	Pumps, Valves, Piping and Structure	Total Subdivision 413.31	-	952,500	44,768	40,310	207,515	1,245,093
	3.2, F-7	Circulating water pumps and motors (3 @ $298,450)	95,000 gpm, 2500 hp, 75 ft. TDH each	-	952,500	44,768	40,310	207,515	1,245,093
	5.4	Circulating water valves, piping & structure	- - -	Included in Subdivision 314.32					

*See page 116 for explanation of footnotes

TABLE XIII. - (Continued)

FEPC Account Number	ECAS Report Ident. No(s).(2)	Account/Subdivision: Title	Account/Subdivision: Description/Specification	Material Costs (3): Major Component	Material Costs (3): Balance of Plant	Installation Cost (3)	Indirect Cost (4)	Contingency Allowance(5	Total Cost
314.32	-	Cooling Towers	Total Subdivision 314.32	-	5,410,200	2,462,213	2,217,03[illegible]	[illegible]	12,1[illegible]7,342
	3.11, F-8	Tower Structure (20 cells)	Mechanical draft towers with fans and motors	-	3,276,600	895,350	806,196	995,629	5,973,775
	5.4, F-2	Tower basin & circulating water system	Circulating water pump pads, riser and concrete envelope for pipe; cooling tower basin; circulating water pipe (I.D. = 123 in.) & valves; misc. steel & fire protection. 246,000 gpm	-	2,133,600	1,566,863	1,410,843	1,022,261	6,133,567
314.4	-	Steam Piping Systems	Total Subdivision 314.4	-	14,363,700	14,101,763	12,697,587	8,232,610	49,395,659
314.41	6.1, F-2	Main Steam	Total Subdivision 314.41 Main steam (I.D. = 15.3 in., t_m=3.97in); hot reheat (I.D.=18.1 in., t_m=2.25 in.); cold reheat (I.D.=32.54 in., t_m=1.57 in.); feedwater (I.D.=26.53 in., 0.675 in.) and condensate large piping, valves and fittings.	-	4,889,500	1,208,723	1,088,365	1,437,317	8,623,905
314.42	6.3	Auxiliary Steam	- - -	Included in Subdivision 314.41					
314.43	-	Miscellaneous Piping Systems	Total Subdivision 314.43	-	9,474,200	12,893,040	11,609,222	6,795,292	40,771,755
	6.3	Other large piping	Auxiliary steam, process water, auxiliary systems	-	5,143,500	3,447,098	3,103,844	2,338,890	14,033,343
	6.4	Small piping	All piping, valves and fittings of 2 in. diameter and less	-	1,714,500	2,268,220	2,042,363	1,205,017	7,230,100
	6.5	Hangers and miscellaneous labor operations	All hangers and supports; material handling; scaffolding and associated miscellaneous labor operations	-	1,803,400	6,252,528	5,629,935	2,737,173	16,423,035
	6.6	Pipe insulation	- - -	-	812,800	925,195	833,06[illegible]	514,[illegible]13	3,[illegible]85,[illegible]

*See page 116 for explanation of footnotes

TABLE XIII. - (Continued)

FERC Account Number	ECAS Report Ident. No(s'. (2)	Account/Subdivision Title	Account/Subdivision Description/Specification	Material Costs (3) Major Component	Material Costs (3) Balance of Plant	Installation Cost (3)	Indirect Cost (4)	Contangency Allowance(5)	Total Cost
314.5	3.12	Other Turbine Plant & Mechanical Equipment	Total Subdivision 314.5 Water treatment & chemical injection, air compressors & auxiliaries; fuel oil handling system, ignition & warmup; screenwell; misc. plant equipment & motors, & equipment insul.	-	2,108,200	447,675	403,098	591,795	3,550,768
315.	-	ACCESSORY ELECTRIC EQUIPMENT	Total Account 315.	-	13,382,400	15,261,840	13,742,150	8,477,278	50,863,668
315.1	4-2	Station and Auxiliary Transformers	Total Subdivision 315.1 Station service and startup transformers; service transformers for boiler and scrubber systems; generator main bus as follows:	-	1,574,400	245,693	221,228	408,264	2,449,584
	E-3, 4	Unit Auxiliary Transformers (2 reqd.)	40/54/67 MVA, 65° C,OA/FA/FOA FOA, 24/13.8 kV, 3-phase, 60Hz	-	-	-	-	-	-
	E-6	Startup Transformer	28/37.5/47 MVA, OA/FA/FOA, 500/13.8 kV, 65° C, 3-phase 60Hz	-	-	-	-	-	-
	E-21, 22	Boiler Auxiliary Transformers (2 reqd.)	5500 kVA, OA, 65° C, 13.8/4.16 kV, 3-phase, 60Hz	-	-	-	-	-	-
	E-25, 26	Scrubber Transformers (2 reqd.)	5000 kVA, OA, 65° C, 13.8/4.16 kV, 3-phase, 60 Hz	-	-	-	-	-	-
315.2	-	Miscellaneous Motors	- - -	Included in Subdivision 314.5					
315.3	4.3	Switchgear & Motor Control Centers	Total Subdivision 315.3 Switchgear, switchyard & load centers; motor control centers; local control stations; distribution panels, relay & meter boards & the following transformers:	-	4,182,000	607,005	546,563	1,067,114	6,402,681

*See page 116 for explanation of footnotes

TABLE XIII. - (Continued)

FERC Account Number	ECAS Report Ident. No(s).(2)	Account/Subdivision: Title	Account/Subdivision: Description/Specification	Material Costs (3): Major Component	Material Costs (3): Balance of Plant	Installation Cost (3)	Indirect Cost (4)	Contingency Allowance (5)	Total Cost
	E-7, 20	Misc. 480 V load control center transformers (14 reqd.)	1689 kVA, OA, 65° C, 13.8kV/480 V/277 V, 3-phase, 60Hz	-	-	-	-	-	-
	E-23, 24	Local control center transformers (2 reqd.)	7000 kVA, OA, 65° C, 13.8/4.16 kV, 3-phase, 60Hz	-	-	-	-	-	-
315.4	4.6	Conduit, Cable Tray, Wire, Cable and Buswork	Total Subdivision 315.4	-	5,018,400	9,133,980	8,224,469	4,475,3[illegible]	[illegible],852,219
315.5	4.4	Miscellaneous Electrical Equipment	Total Subdivision 315.5	-	2,472,300	5,246,258	4,723,864	2,488,464	14,[illegible],9[illegible]
			Communications; grounding; cathodic & freeze protection; lighting; pre-operational testing						
315.6	-	Integrated Control System	- - -	Included in Subdivision 312.42					
315.7	-	Data Acquisition System	- - -	Included in Subdivision 312.42					
315.8	4.5, E-5	Emergency Power System	Total Subdivision 315.8	-	135,300	28,905	26,027	38,046	228,278
			Diesel generator, batteries & associated d.c. equipment. 1000 KW, 3-phase, 60 Hz, 480 V, 0.8 pf.						
316.	-	MISCELLANEOUS POWER PLANT EQUIPMENT	Total Account 316.	-	350,000	14,688	13,225	75,583	453,495
316.1	-	Fuel Oil Handling System	- - -	Included in Subdivision 314.5					
316.2	-	Fire Protection System	- - -	Included in Subdivision 311.14					
316.3	7.6	Machine & Maintenance Shops	- - -	-	350,000	14,688	13,225	75,583	453,495

*See page 116 for explanation of footnotes

TABLE XIII. - (Concluded)

FERC Account Number	ECAS Report Ident. No(s).(2)	Account/Subdivision: Title	Account/Subdivision: Description/Specification	Material Costs (3): Major Component	Material Costs (3): Balance of Plant	Installation Cost (3)	Indirect Cost (4)	Contingency Allowance (5)	Total Cost
350.	-	TRANSMISSION PLANT	Total Account 350.	-	2,323,000	54,050	48,668	485,144	2,910,862
350.1	5.1, 5.2, 5.3	Structures & Improvements	- - -	Included in Subdivision 311.3					
350.2	4.1, E-1.2	Main Transformers	Total Subdivision 350.2 468 MVA, FOA, 65°C, 24/500 kV	-	2,323,000	54,050	48,668	485,144	2,910,862
350.3	4.3	Switchyard	- - -	Included in Subdivision 315.3					
		Total of Direct Accounts 310. to 350.		93,237,700	125,205,520	78,429,548	70,619,668	73,498,487	440,990,923
		A/E Services & Fee @ 18% of Balance of Plant Materials, Installation & Indirect Costs (9)							49,365,852
		Plant Capital Cost							490,356,775
		Escalation & Interest During Construction @ 54.8 percent (5.5 yr. Constr. per 6.5 percent escalation rate, 10 percent interest rate) (10)							268,715,513
		Total Plant Capital Cost in Jan. 1984 Dollars							759,072,[illegible]
		Total Plant Capital Cost De-Escalated to mid-1978 (11)							536,859,069

*See pages 116 and 117 for explanation of footnotes

NOTES TO TABLE XIII

(1) Based on ECAS report tables 27 and 28 (Ref. 7).

(2) Identification numbers consisting of letters and numerals refer to table 27 of the ECAS report, reproduced in Appendix C pages 188 to 191, for reference. Identification numbers consisting of numerals only refer to table 28 of the ECAS report, reproduced in Appendix C pages 192 to 198, for reference. References to other ECAS report tables are as indicated. The letter (M) following an identification number(s) indicates that the description/specification of the item in that subdivision is modified relative to that in the ECAS reference plant (see also table V).

(3) Escalated from the mid-1975 value listed in table XXXIII using the account specific escalation factor listed in table XXV except for the major component and balance-of-plant costs in FERC Accounts 312.7 and 312.8, which were determined from a manufacturer's verbal budget cost estimate.

(4) See Note 3.

(5) Based on the 20 percent contingency rate included in the ECAS report (Ref. 7, page 44).

(6) The costs of the buildings, structures and excavations listed in Accounts 311.3, 311.4, 311.6, 311.7, 311.9 and 312.1 are calculated using the estimated percentages of the sum of the costs of Items 5.1, 5.2 and 5.3 of Ref. 7, table 28 listed in Appendix C, page 199, table XXX, escalated to mid-1978 dollars using the account specific factors for Accounts 311. and 312., where appropriate, listed in table XXV. Note that the same table applies to both the 250^{O} and 175^{O} F (394^{O} and 353^{O} K) reheat cases.

(7) The separate balance-of-plant materials costs for the feedwater booster (2) and main feedwater (3) pumps are estimated from the combined balance-of-plant materials cost of these five pumps ($3,220,000) listed in Ref. 7, table 28, as follows: The combined equipment cost of the pumps $3,070,000 ((2) ($125,000) + (3) ($940,000)) is subtracted from the combined balance-of-plant

NOTES TO TABLE XIII (Concluded)

materials cost and the remainder ($150,000) divided by the total horsepower of the five pumps (45,500 hp) resulting in $3.30/hp. This cost per horsepower is then multiplied by the horsepower of the two feedwater booster pumps, for example, to give $25,410 (7700 hp x $3.30/hp) and the equipment cost of the two pumps, $250,000, added to the product to give $275,410. This figure is then escalated to mid-1978 dollars ($341,500) using the 1.24 factor for the FERC Account 312. listed in table XXV. Similarly, the cost of the main feedwater pumps is estimated as $2,944,740 (i.e., ($3.30/hp) (38,700 hp) + 3($940,000)), which is escalated to $3,651,500.

(8) The separate balance-of-plant materials costs for the stack gas reheat system forced draft fans and reheat air heaters are estimated from the combined $900,000 balance-of-plant materials cost listed in Ref. 7, table 28, as follows: The combined equipment cost of the fans and heaters, $810,000 (6 x $85,000 + $50,000), is subtracted from the combined balance-of-plant materials cost. The remainder, $90,000 is divided equally between the fans and heaters, and one $45,000 part is added to the equipment cost of the fans and the other to the equipment cost of the heaters to give $555,000 and $345,000 for the respective balance-of-plant materials costs of each. These values are escalated to mid-1978 dollars $688,200 and $427,800, respectively) using the 1.24 factor for FERC Account 312. listed in table XXV.

(9) Includes the 20 percent contingency in Note 5 applied to the 15 percent A/E services and fee rate employed in the ECAS report (Ref. 7, page 44) to account for the change in the order of applying the contingency and A/E services and fee rates in this study compared to the ECAS study.

(10) Based on the guidelines specified by NASA for the ECAS study (Ref. 4).

(11) The sum of the Plant Capital Cost and Escalation and Interest During Construction divided by $(1.065)^{5.5}$ to de-escalate the Total Plant Capital Cost in Jan. 1984 at the completion of the 5.5 year construction period to mid-1978.

to the sum of these escalated costs to compute a new contingency allowance which was then added to the sum to compute the updated total cost of the account.

To calculate the A/E services and fee, listed at the end of each cost estimate, an 18 percent rate was applied to the sum of the balance-of-plant materials, installation and indirect costs. Superficially, this appears to differ from the 15 percent rate employed in the ECAS study (Ref. 7). However, its equivalence becomes clear onece it is recognized that in the ECAS study, the 20 percent contingency was applied to the combined A/E Services and Fee and account subtotals, whereas in this study it is applied only to the account subtotals. The A/E Services and Fee in this study is therefore increased by 20 percent to compensate and keep the total plant costs on an equivalent basis.

8.0 COST SUMMARY COMPARISONS AND COST OF ELECTRICITY

This section presents summary comparisons of the six detailed capital cost estimates included in section 7.2 and Appendix E. It also presents the results of a calculation of the cost of electricity for each plant design and estimate year, based, in part, on the totals of the capital cost estimates.

8.1 Modified Reference Plant Versus ECAS Reference Plant: Mid-1978

Table XIV presents a comparison of the mid-1978 capital costs, presented in tables X to XIII, for both the 250^{o} and 175^{o} F (394^{o} and 353^{o} K) stack gas reheat temperatures. Each of the FERC account costs as of mid-1978, except for those of the electrostatic precipitator and sulfur dioxide scrubber, which were obtained by a verbal cost estimate from a pollution control equipment manufacturer, is computed in a straightforward manner from the corresponding costs as of mid-1975 by the method discussed in section 7.2 That is, a separate escalation factor, listed in table XXV, calculated from the Handy-Whitman Index of Public Utility Construction Costs (Ref. 9), is applied to each FERC account. To calculate the A/E services and fee, an 18 percent rate is applied to the sum of all the balance-of-plant materials, installation and indirect costs that make up the FERC accounts. On the surface, this appears to differ from the 15 percent rate employed in the ECAS study (Ref. 7). However, as discussed in section 7.2, it is actually equivalent to the ECAS rate increased by 20 percent to account for the reversed order of applying the contingency rate in this study compared with that used in the ECAS study.

It is apparent from table XIV that for each reheat temperature, the corresponding modified and ECAS reference plants have essentially the same total cost. This may appear surprising at first, since the modified plant is designed to comply with the more stringent EPA June 1979 New Source Performance Standards and is therefore expected to include more expensive pollution control components. However, offsetting incremental costs are present.

TABLE XIV. - MODIFIED AND ECAS REFERENCE CONVENTIONAL FURNACE COAL-FIRED POWER PLANTS WITH WET SO_2 SCRUBBERS COMPARISON OF CAPITAL COST ESTIMATE SUMMARIES (10^3\$ Rounded)

FERC Acct No.	Account Title	Modified Reference Plant		ECAS Reference Plant	
		Stack Gas Reheat Temperature, °F (°K)			
		250 (394) [1]	175 (353) [2]	250 (394) [3]	175 (353) [4]
310.	LAND AND LAND RIGHTS	—— Not Included in Study ——			
311.	STRUCTURES & IMPROVEMENTS	43,846	43,846	43,846	43,846
312.	BOILER PLANT	237,876	227,318	237,495	226,901
314.	STEAM TURBINE-GENERATOR AND AUXILIARIES	112,244	115,599	112,244	115,599
315.	ACCESSORY ELECTRIC EQUIPMENT	50,864	50,864	50,864	50,864
316.	MISCELLANEOUS POWER PLANT EQUIPMENT	453	453	453	453
350.	TRANSMISSION PLANT	2,911	2,911	2,911	2,911
	Total of Accounts 310. to 350.	448,194	440,991	447,813	440,574
	A/E Home Office and Fee @ 18 Percent of Balance-of-Plant Materials, Installation and Indirect Costs. (Includes a 20 percent contingency consistent with the contingency applied to the total plant cost in the ECAS Report (Ref. 7)).	50,618	49,366	50,988	49,731
	Plant Capital Cost	498,812	490,357	498,801	490,305
	Escalation and Interest During Construction @ 54.8 Percent (5.5 yr. constr. per 6.5 percent escalation rate, 10 percent interest rate)(5)	273,349	268,715	273,343	268,687
	Total Plant Capital Cost in January 1984 Dollars	772,161	759,072	772,144	758,992
	Total Plant Capital Cost De-escalated to Mid-1978 (6)	546,116	536,859	546,104	536,802

(1) Based on the components and costs listed in tables XXVI and XXVII. See table XII for cost details.

(2) Based on the components and costs listed in tables XXVIII and XXIX. See table XIII for cost details.

(3) Based on the components and costs listed in tables XXVI and XXVII. See table X for cost details.

(4) Based on the components and costs listed in tables XXVIII and XXIX. See table XI for cost details.

(5) Based on the guidelines specified in the ECAS Study (Ref. 4).

(6) Plant Capital Cost and Escalation and Interest During Construction divided by $(1.065)^{5.5}$ to de-escalate the Total Plant Capital Cost in Jan. 1984 at the completion of the 5.5 year construction period to mid-1978.

In the modified plant, in contrast to the ECAS plant, on-site lime production is omitted reducing the estimated plant installed equipment cost by $7,639,065 (see tables V and X to XIII, FERC Account Subdivision No. 312.83). On the other hand, more efficient electrostatic precipitator and sulfur dioxide scrubber systems are included (see tables X to XIII, FERC Account Subdivision Nos. 312.71 and 312.81) increasing the plant installed equipment costs by $7,706,881, for the 250° F (394° K) reheat temperature case (i.e., $2,848,801 for the electrostatic precipitator and $4,858,080 for the sulfur dioxide scrubber), and $7,741,921, for the 175° F (353° K) reheat temperature case (i.e., $2,848,801 for the electrostatic precipitator and $4,893,120 for the sulfur dioxide scrubber). After including $313,920 in the modified plant, for both reheat temperatures, to account for the increased cost of the foundations and structures required for the larger scrubber and associated auxiliaries, the cost of the modified plant is only about $381,816 more than the ECAS plant, for the 250° F (394° K) reheat temperature case, and $416,856, for the 175° F (353° K) reheat temperature case.

Adding the A/E home office and fee, and escalation and interest during construction, the total capital cost of the modified plant is calculated to be $772,161 compared to $772,144, for the 250° F (394° K) reheat temperature case, and $759,072 compared to $758,992 for the 175° F (353° K) reheat temperature case. Considering these two comparisons further, it is seen that their respective parts are within 17 percent of one another. To within the accuracy of this study, therefore, they may be considered to be equal.

Lastly, it may be noted that by reducing the stack gas reheat temperature, an estimated $13 million reduction in total plant capital cost results. This, as discussed in section 8.3, leads to a significant reduction in the cost of electricity.

8.2 ECAS Reference Plant Capital Costs: Mid-1978 Versus Mid-1975

Table XV presents a comparison of the updated mid-1978 capital costs of the ECAS reference plant listed in tables X and XI, respectively, with the mid-1975 capital costs, listed in tables XXXII

TABLE XV. - ECAS REFERENCE CONVENTIONAL FURNACE COAL-FIRED POWER PLANT WITH WET SO_2 SCRUBBER COMPARISON OF CAPITAL COST ESTIMATE SUMMARIES AS OF MID-1978 AND MID-1975 (10^3\$ Rounded)

FERC Acct No.	Account Title	Mid-1975 Stack Gas Reheat Temperature, °F (°K) 250 (394)[1]	Mid-1975 175 (353)[2]	Mid-1978 250 (394)[3]	Mid-1978 175 (353)[4]
310.	LAND AND LAND RIGHTS	— Not Included in Study —			
311.	STRUCTURES AND IMPROVEMENTS	37,798	37,798	43,846	43,846
312.	BOILER PLANT	191,528	182,985	237,495	226,901
314.	STEAM TURBINE-GENERATOR AND AUXILIARIES	88,381	91,023	112,244	115,599
315.	ACCESSORY ELECTRIC EQUIPMENT	41,353	41,353	50,864	50,864
316.	MISCELLANEOUS POWER PLANT EQUIPMENT	363	363	453	453
350.	TRANSMISSION PLANT	2,531	2,531	2,911	2,911
	Total of Accounts 310. to 350.	361,954	356,052	447,813	440,574
	A/E Home Office and Fee @ 18 Percent of Balance-of-Plant Materials, Installation and Indirect Costs. (Includes a 20 percent contingency consistent with the contingency applied to the total plant cost in the ECAS Report (Ref. 7)).				
	Plant Capital Cost in Dollars	403,308	396,387	498,801	490,305
	Escalation and Interest During Construction @ 54.8 Percent (5.5 yr. constr. per 6.5 percent escalation rate, 10 percent interest rate)(5)				
	Total Plant Capital Cost in Dollars of the Year of Construction Completion	624,321	613,607	772,144	758,992

(1) Based on the components and costs listed in tables XXVI and XXVII. See table XXXII for details.
(2) Based on the components and costs listed in tables XXVIII and XXIX. See table XXXIII for details.
(3) Based on the components and costs listed in tables XXVI and XXVII. See table X for escalated cost details.
(4) Based on the components and costs listed in tables XXVIII and XXIX. See table XI for escalated cost details.
(5) Based on the guidelines specified in the ECAS Study (Ref. 4).

and XXXIII. Both the 250° and 175° F (394° and 353° K) stack gas reheat cases are included. Tables XXXII and XXXIII list the same costs as those presented in the ECAS study (Ref. 7), changed in format to meet the requirements of this study.

From table XV, the total plant capital costs, as of mid-1978, are seen to be $772,144,000, for the 250° F (394° K) reheat temperature case, and $758,992,000, for the 175° F (353° K) reheat temperature case. Similarly, the total plant capital costs, as of mid-1975, are seen to be $624,321,000 for the 250° F (394° K) reheat temperature case, and $613,607,000, for the 175° F (353° K) reheat temperature case.

Calculating the ratios of the corresponding total plant capital costs as of mid-1978 and mid-1975, the escalation of the total plant capital cost is 23.7 percent for both reheat temperature cases and the 3-year period considered in this study. Effectively, this amounts to an escalation of about 7.3 percent per year.

8.3 Cost of Electricity

Table XVI presents a comparison of the levelized costs of electricity of the four plant designs and two estimate years considered in this study. Listed in the upper part of the table are the plant specific parameters which are used in the relationship discussed in section 3.4, to calculate the cost components of the levelized cost of electricity which are listed in the lower part of the table. For reference, the total plant costs for all cases, expressed in $/kWe (net), are also included.

The last two columns of the table list the parameters and the cost of electricity, as of mid-1975, of the two ECAS reference plant reheat temperature cases (Ref. 7). Due to the fact that levelization of the fuel and operation and maintenance costs was not employed in the ECAS study, the costs of electricity listed in table XVI for these cases, 53.1 mills/kWh (250° F (394° K) reheat) and 49.6 mills/kWh (175° F (353° K) reheat), differ significantly from those listed in tables 21 and 31 of the ECAS study (Ref. 7),

TABLE XVI. - COST OF ELECTRICITY COMPARISON (1)

	Modified Reference Plant		ECAS Reference Plant	
	Stack Gas Reheat Temperature, $^{\circ}F$ ($^{\circ}K$)			
	250 (394)	175 (353)	250 (394)	175 (353)
Total Plant Capital Cost				
De-escalated to mid-1978 (10^6 \$)	546.1	536.9	546.1	536.8
\$/kW_e (net)	731	675	731	675
Net Plant Power Power Output (at 100 percent operation) (MW)	747.2	795.5	747.2	795.5
Overall Plant Efficiency (percent)	32.3	34.3	31.8	33.8
Cost of Electricity Components (mills/kWh) (2):				
Capital	23.1	21.3	23.1	21.3
Fuel	22.2	20.9	22.6	21.2
Operation and maintenance (3)	6.6	6.4	6.6	6.4
Cost of Electricity (mills/kWh)	51.9	48.6	52.3	48.9

1. Based on the total capital costs listed in tables X to XIII, XXXII and XXXIII; net plant power outputs listed in table VI and Ref. 7, tables 21 and 31; overall plant efficiencies listed in table VIII and Ref. 7, tables 21 and 31; and the cost of electricity components listed in Ref. 7, tables 21 and 31.
2. Based on 18 percent fixed charge rate, 65 percent capacity factor, \$1.05/10^6 Btu fuel cost (\$1.00/10^6 Btu for mid-1975 ECAS reference plant), 2.004 levelizing factor for fuel and operation and maintenance costs, and the mathematical relationship presented in section 3.5.
3. Escalated at 8.5 percent per year from the mid-1975 ECAS study value.

39.8 mills/kWh (250° F (394° K) reheat) and 37.0 mills/kWh (175° F (353° K) reheat).

Comparing the cost of electricity for each of the reheat cases as of mid-1978, the modified reference plant values are seen to be lower: 61.5 mills/kWh compared to 61.9 mills/kWh, for the 250° F (394° K) reheat temperature case, and 57.5 mills/kWh compared to 57.8 mills/kWh, for the 175° F (353° K) reheat temperature case. This results principally from the deletion of on-site lime production from the modified plant. Deleting on-site lime production results in an increase of about 0.5 percent in the overall plant efficiency, due to not requiring energy to operate the calciner, and consequent reduction in fuel cost, due to more efficient operation. It also reduces the operation and maintenance costs. However, since this reduction is offset by an increase in the amount of limestone and limestone handling required for the wet limestone sulfur dioxide scrubber, the effect of deleting on-site lime production on plant operation and maintenance is not included.

9.0 REFERENCES

1. "Code of Federal Regulations (CFR)," Title 40, Protection of Environment, Part 60 - Standards of Performance for New Stationary Sources, Subpart D - Standards of Performance for Fossil-Fuel Fired Steam Generators (40 CFR 60.40 et seq.), 1971.

2. Federal Register, Vol. 44, No. 113, Rules and Regulations, Part II, Environmental Protection Agency, New Source Performance Standards; Electric Utility Steam Generating Units, 40 CFR Part 60, June 11, 1979.

3. "Code of Federal Regulations," Title 40, Protection of Environment, Part 60 - Standards of Performance for New Stationary Sources, Subpart F - Standards of Performance for Portland Cement Plants (40 CFR 60.60 et seq.), 1977.

4. "Comparative Evaluation of Phase I Results From the Energy Conversion Alternatives Study (ECAS)" NASA TM X-71855, 1976.

5. "Engineering Test Facility Conceptual Design," Final Report, Part 1, Avco Everett Research Laboratory, Inc., DOE Fe-2614-2 (Pt. 1), June 1978.

6. "Guide for Economic Evaluations of Nuclear Reactor Plant Designs," NUS Corporation. Rockville, Maryland, NUS-531, January 1969.

7. Brown, D. H., "Energy Conversion Alternatives Study (ECAS), Conceptual Design and Implementation Assessment of a Utility Steam Plant With Conventional Furnace and Wet Lime Stack Gas Scrubbers," General Electric Company, NASA CR-134950, SRD-76-064-4, 1976.

8. "Uniform Systems of Accounts Prescribed for Public Utilities and Licensees (Classes A, B, C and D) Subject to the Provisions of the Federal Power Act (49 Stat. 838)." Including the Additions and Amendments through Transmittal Sheet No. 3, dated Jan. 1, 1979, to the Edition in Effect on April 1, 1973, U.S.A. Federal Energy Regulatory Commission (formerly the Federal Power Commission (FPC)).

9. "The Handy-Whitman Index of Public Utility Construction Costs," Bulletin No. 110 to July 1, 1979, Compiled and Published by Whitman, Requardt and Associates, Baltimore, Maryland.

Appendix A

Technical Assessments

This appendix contains the text of the five technical assessments on which the modification of the ECAS reference plant is based. The subjects covered include

1. Sulfur Dioxide Scrubber System Design
2. On-site Calcination Process Versus Purchased Lime
3. Reheat of Stack Gas: Method-Selection Preference
4. Effect of Sulfur Dioxide Scrubber on Particulate Emissions
5. Control of Nitrogen Oxides

Each of the assessments was carried out in sufficient detail to define the impact of its subject matter on the ECAS plant design and the changes necessary to permit the ECAS plant to meet the June 1979 New Source Performance Standards.

A1.0 SO_2 SCRUBBER SYSTEM DESIGN

The ECAS scrubber system (Ref. A1) was designed for 90 percent reduction of SO_2 emissions for a coal containing 4.5 percent (by wt) sulfur. However, the Illinois No. 6 coal analysis, on which the remainder of the study is based, shows 3.9 percent (by wt) sulfur, and the Illinois No. 6 coal analysis, on which the more recent Engineering Test Facility (ETF) study (Ref. A2) is based, shows 3.3 percent (by wt) sulfur.

Question: Should the design sulfur content margin be retained or modified? If modified, what value should be used?

A1.1 Summary and Conclusions

The relevant parameter upon which the design of a sulfur emission control system is based is "lb SO_2/million Btu" heat input. Therefore, the percent sulfur for any coal must be related to the corresponding heating value of that coal to determine the removal efficiency required to meet established pollution standards. The ECAS Study indicates only the design sulfur content for the scrubber design without specifying the relevant EPA design parameter of lb $SO_2/10^6$ Btu heat input.

It is recommended that the scrubber specification be defined based on potential emissions of 8.3 lbs SO_2 per million Btu of heat input which corresponds to a coal having a design sulfur content of 4.5 percent sulfur and a design heat content of 10,788 Btu/lb. The scrubber will be designed for a sulfur dioxide removal efficiency of 90 percent which is the value required to meet the 1979 NSPS standards for this level of potential emissions. It is also anticipated that this efficiency will be acceptable to the cognizant regulatory agencies as the Best Available Control Technology (BACT) and therefore is acceptable as the flue gas desulfurization (FGD) system design efficiency. It is concluded that the selection of 4.5 percent sulfur for the design of the scrubber in the ECAS study was reasonable and conservative.

It is also recommended that the Reference Plant be capable of burning both the ECAS and ETF coals with ranges of properties in accordance with usual power plant practice, i.e., equipment should be capable of operating satisfactorily with any coal having characteristics within specified ranges even though performance guarantees are for only one coal with each characteristic having one specific value.

A1.2 Discussion

Table XVII lists the characteristics of the Illinois No. 6 coals used in the ECAS and ETF Studies. These coals are representative of coals which are currently being mined in Illinois (Ref. A3). For example, the ECAS coal corresponds closely to one being mined in Macoupin County, whose properties are listed in table XVIII, while the ETF coal closely corresponds to one being mined in Perry County, whose properties are listed in table XIX. During 1976, about 3,300,000 tons of coal were extracted from the mines in Macoupin County, while 11,400,000 tons were extracted from the mines in Perry County (Ref. A3). Since 1882, these counties have produced about 280,700,000 tons and 318,600,000 tons respectively (Ref. A3). Therefore, on the basis of availability there is no overriding reason to prefer either of these coals for study purposes.

In addition, utilities do not usually limit themselves to a single source of supply. Common practice is to provide for more than one source of fuel to assure a fuel supply in case of a disruption of the supply from its primary source and to provide a secure fuel supply over the life of the plant. Assuming that the costs of the two coals are comparable, a typical utility would probably arrange for a backup alternate fuel source. It is therefore recommended that the reference plant be capable of burning both the ECAS and ETF fuels.

The proximate and ultimate analyses used in the ECAS and ETF studies (table XVII) do not indicate any ranges for the composition normally encountered in an actual coal supply. Although it is not

TABLE XVII. - ANALYSES OF ILLINOIS NO. 6 BITUMINOUS COALS AND ASH EMPLOYED IN PREVIOUS STUDIES

	ECAS (1)	ETF (2)
Proximate Analysis (As Received), percent (wt)		
Moisture	13.0	8.9
Volatile matter	36.7	38.0
Fixed carbon	40.7	41.7
Ash	9.6	11.4
Ultimate Analysis (As Received), percent (wt)		
Sulfur	3.9	3.3
Hydrogen	5.9	5.4
Carbon	59.6	62.4
Nitrogen	1.0	1.2
Oxygen	20.0	16.3
Ash	9.6	11.4
Higher Heat Value (As Received), Btu/lb	10788	11265
Coal Rank	HVCB	HVCB
Ash Analysis, percent (wt)		
SiO_2	46.6	41.4 ± 5.4
Al_2O_3	19.3	19.3 ± 6.8
Fe_2O_3	20.8	22.3 ± 6.8
TiO_2	0.8	0.9
P_2O_5	0.24	0.12
CaO	7.7	5.4 ± 3.3
MgO	0.9	1.7 ± 1.3
Na_2O	0.2	0.6 ± 0.2
K_2O	1.7	2.1 ± 0.4
SO_3	2.4	7.5 ± 0.6
Initial Deformation Temp., $^{\circ}F$ ($^{\circ}K$)	1990-2130 (1361-1439)	1960 ± 70 (1344 ± 39)
Softening Temp., $^{\circ}F$ ($^{\circ}K$)	1979 (1355)	2030 ± 70 (1383 ± 39)
Fluid Temp., $^{\circ}F$ ($^{\circ}K$)	2090-2440 (1416-1611)	2260 ± 200 (1511 ± 111)
Grindability H.G.I.	52-56	Not Reported
Average	55	Not Reported

1. As listed in the "Energy Conversion Alternatives Study," February 1976. (Ref. A6)
2. As listed in the "Engineering Test Facility Conceptual Design," Avco Everett Research Lab., Inc., June 1978. (Ref. A2)

TABLE XVIII. - MACOUPIN COUNTY MINE AVERAGES OF PROXIMATE AND ULTIMATE ANALYSES (1)

Mine Index Number	Proximate Analysis (percent wt)				Ultimate Analysis (percent wt)					HV	Potential Emissions (3)
	Moisture	Volatile Matter	Fixed Carbon	Ash	S Sulfur	Hydrogen	Carbon	Nitrogen	Oxygen	Heat Value Btu/lb	lb SO_2 / 10^6 Btu
66	14.2	38.7	37.1	10.0	4.3	-	-	-	-	10550	8.2
67	14.9	37.2	37.9	10.0	3.9	-	-	-	-	10590	7.4
68	12.9	39.2	38.7	9.2	4.6	-	-	-	-	10960	8.4
69	14.2	37.4	37.0	11.4	4.4	-	-	-	-	10440	8.4
185	11.9	39.3	39.7	9.1	3.6	5.8	60.9	1.1	19.5	11040	6.5
186	11.2	37.8	40.4	10.6	3.9	5.9	60.2	1.1	18.3	10900	7.2
187	13.5	36.4	38.9	11.2	4.2	5.8	57.8	1.0	20.0	10580	7.9
188	12.0	38.7	40.9	8.4	3.9	5.9	61.1	1.1	19.6	11090	7.0
189	14.1	35.3	41.7	8.9	4.0	5.9	58.6	1.1	21.5	10590	7.5
190	14.1	34.4	42.4	9.1	3.4	6.0	58.8	1.1	21.6	10650	6.4
503	13.7	34.7	42.4	9.2	4.1	-	-	-	-	10840	7.6
534	13.8	36.0	40.2	10.0	4.1	5.7	59.2	1.0	20.0	10680	7.7
Mean	13.4	37.1	39.8	9.8	4.0	5.9	59.5	1.1	20.1	10743	7.5
Std. Dev. (2)	1.1	1.7	1.9	0.9	0.3	0.1	1.2	0.05	1.2	214	0.7

1. As listed in references A4 and A5 for samples as received. Each entry is a composite of measurements for 2 to 3 samples. Data from Bureau of Mines Technical Paper 641 are incorporated.

2. Assuming measured quantities are distributed in a statistically normal manner.

3. $\text{lb } SO_2/10^6 \text{ Btu} = \frac{2 \times \text{percent S}}{HV}$

TABLE XIX. - PERRY COUNTY (WEST OF DUQUOIN ANTICLINE) MINE AVERAGES OF PROXIMATE AND ULTIMATE ANALYSES (1)

Mine Index Number	Proximate Analysis (percent wt)				Ultimate Analysis (percent wt)					HV	Potential Emissions (3)
	Moisture	Volatile Matter	Fixed Carbon	Ash	S Sulfur	Hydrogen	Carbon	Nitrogen	Oxygen	Heat Value (Btu/lb)	$\frac{lb\ SO_2}{10^6\ Btu}$
88	9.6	37.1	41.3	12.0	3.8	-	-	-	-	10980	6.9
89	12.5	36.[illegible]	42.8	8.6	2.8	-	-	-	-	11210	5.0
90	10.7	[illegible]	42.5	10.3	3.6	5.4	61.8	1.1	17.8	11080	6.5
175	10.1	35.7	43.8	10.4	3.7	-	-	-	-	11190	6.6
176	10.2	36.4	43.3	10.1	3.4	-	-	-	-	11180	6.1
178	9.8	35.0	42.5	12.7	4.1	-	-	-	-	10820	7.6
179	8.8	37.4	43.0	10.8	3.4	-	-	-	-	11300	6.0
182	9.1	35.8	43.9	11.2	3.7	-	-	-	-	11140	6.6
184	8.0	38.2	42.6	11.2	3.6	-	-	-	-	11290	6.4
622	9.2	35.6	44.2	11.0	3.7	5.2	62.3	1.0	16.8	11290	6.6
623	10.2	35.0	44.4	10.4	3.5	5.4	61.6	1.1	18.0	11160	6.3
633	10.2	36.6	42.7	10.5	3.4	5.5	62.3	1.4	16.9	11210	6.1
873	12.0	33.9	44.9	9.2	1.5	5.5	63.2	1.3	19.3	11230	2.7
Mean	10.0	36.1	43.2	10.6	3.4	5.4	62.2	1.2	17.8	11160	6.1
Std. Dev. (2)	1.2	1.1	1.0	1.1	0.6	0.1	0.6	0.2	1.0	135	1.2

1. As listed in references A4 and A5 for samples as received. Each entry is a composite of measurements for 2 to 6 samples. Data from Bureau of Mines Technical Paper 641 are incorporated.

2. Assuming measured quantities are distributed in a statistically normal manner.

3. $lb\ SO_2/10^6\ Btu = \frac{2 \times \text{percent S}}{HV}$

so stated, it is assumed that the values used are averages for many samples. This is consistent with the coal analyses of actual samples presented in tables XVIII and XIX. Tables XVIII and XIX indicate, however, that, for any one constituent of a series of samples from a mine, there is a range of values above and below the mean value of the constituent. For example, the twelve coal samples from Macoupin County have a mean sulfur content of 4.0 percent (table XVIII) and a standard deviation of 0.3 percent. The thirteen coal samples from Perry County have a mean sulfur content of 3.4 percent (table XIX) and a standard deviation of 0.6 percent. Similarly, based on the sulfur content and heat values of the individual samples tested, the lb SO_2 per million Btu heat input, derived from the sample sulfur concentrations and heat values, is calculated to have a standard deviation of 0.7 percent, based on the Macoupin County samples, and 1.2 percent, based on the Perry County samples.

The air quality control regulatory agencies usually require that emissions from a power plant not exceed the approved maximum over a specified period, such as a 30-day rolling average. In addition, this maximum must not be exceeded with the worst fuel likely to be fired. In general, the design value for potential emissions will be one to two standard deviations higher than the mean value depending on the degree of conservatism required. Thus, if a value of the SO_2 per million Btu heat input is selected which is a little greater than one standard deviation larger than the mean, there is about 85 percent confidence (based on a one-sided tolerance interval) that all the coal received during the life of the plant from the mines will have an SO_2 per million Btu value less than this design value, assuming a statistically normal distribution around the mean value. Based on a comparison with the Macoupin County samples, the design SO_2 per million Btu value selected in the ECAS study appears to be about 1.14 standard deviations higher than the mean, within the acceptable range.

The design SO_2 potential emission quantity may be reduced by the amount of sulfur retained in the ash collected within the

steam generator and particulate collection equipment. Some sulfur in the coal is retained with the bottom ash and some of the SO_2 generated reacts with the alkaline constituents in the fly and bottom ash. EPA document AP42 (Ref. A7) provides guidelines for estimating the retention of sulfur in the ash. For this application, a reduction of about five percent in the SO_2 potential emission level can be derived from the AP42 guidelines. Since this reduction does not change the required removal efficiency of the flue gas desulfurization system, it is recommended that no credit be taken for this reduction, which will provide a degree of conservatism in meeting emission limits.

Table XX lists the selected properties of the two Illinois No. 6 coals used in the present study. It incorporates the recommendations of the foregoing paragraphs; i.e., ranges of properties rather than single values. The primary coal corresponds to that used in the ECAS study and the alternate coal to that used in the ETF study. For both coals, standard deviations are included for each constituent for use in the study where variations from the mean are significant. To determine the standard deviations without a set of analyses it has been assumed that the standard deviations are the same percentages of the mean values as those listed for the corresponding items in tables XVIII and XIX. The standard deviations for the components of the ash analysis are the same percentages of the mean values as those listed for the ETF coal in table XVII. For completeness, standard deviations are listed for TiO_2 and P_2O_5, based on an average of the percentages of the means (34 percent) of the other ash analysis constituents of the ETF coal. The TiO_2 and P_2O_5, however, do not significantly affect the plant design.

Applying table XX, in conjunction with the foregoing considerations, to the ECAS and ETF coals, and selecting a design sulfur content of 4.5 percent (two standard deviations above the mean for both coals) and an average heat value of 10,788 Btu/lb (the mean of the ECAS coal and about four standard deviations below the mean of the ETF coal), the design potential SO_2 emissions are 8.3 lbs SO_2

TABLE XX. - SELECTED PROPERTIES OF ILLINOIS NO. 6 BITUMINOUS COALS USED IN PRESENT STUDY

	Primary Coal (1)			Alternate Coal (2)		
	Mean	Std. Dev.	(Percent of Mean)(3)	Mean	Std. Dev.	(Percent of Mean)(4)
Proximate Analysis (As Received), percent(wt)						
Moisture	13.0	1.1	(8.2)	8.9	1.1	(12)
Volatile Matter	36.7	1.7	(4.6)	38.0	1.1	(3.0)
Fixed Carbon	40.7	2.0	(4.8)	41.7	1.0	(2.3)
Ash	9.6	0.9	(9.2)	11.4	1.1	(10)
Ultimate Analysis (As Received), percent(wt)						
Sulfur	3.9	0.3	(7.5)	3.3	0.6	(18)
Hydrogen	5.9	0.1	(1.7)	5.4	0.1	(1.9)
Carbon	59.6	1.2	(2.0)	62.4	0.6	(1.0)
Nitrogen	1.0	0.05	(4.5)	1.2	0.02	(17)
Oxygen	20.0	1.2	(6.0)	16.3	0.9	(5.6)
Ash	9.6	0.9	(9.2)	11.4	1.1	(10)
Higher Heat Value (As Received), Btu/lb	10788	216	(2.0)	11265	135	(1.2)
Coal Rank	HVCB	-	-	HVCB	-	-
Ash Analysis, percent(wt)						
SiO_2	46.6	6.1	(13)	41.4	5.4	(13)
Al_2O_3	19.3	6.8	(35)	19.3	6.8	(35)
Fe_2O_3	20.8	6.3	(30)	22.3	6.8	(30)
TiO_2	0.8	0.3	(34)	0.9	0.3	(34)
P_2O_5	0.24	0.1	(34)	0.12	0.04	(34)
CaO	7.7	4.7	(61)	5.4	3.3	(61)
MgO	0.9	0.7	(76)	1.7	1.3	(76)
Na_2O	0.2	0.1	(33)	0.6	0.2	(33)
K_2O	1.7	0.3	(19)	2.1	0.4	(19)
SO_3	2.4	0.2	(8.0)	7.5	0.6	(8.0)
Initial Deformation Temp., °F (°K)	2050 (1394)	70(39)	(3.4)	1960 (1344)	70(39)	(3.6)
Softening Temp., °F (°K)	1979 (1355)	68(38)	(3.4)	2030 (1383)	70(39)	(3.4)
Fluid Temp., °F (°K)	2265 (1514)	175(97)	(7.7)	2260 (1511)	200(111)	(8.8)
Grindability H.G.I.	54	2	(3.7)	54	2	(3.7)(5)

*See page 137 for explanation of footnotes

NOTES TO TABLE XX

(1) Corresponds to that used in the ECAS study (Ref. A6).

(2) Corresponds to that used in the ETF study (Ref. A2).

(3) Percent of mean = (Std. Deviation ÷ mean) x 100. For the proximate and ultimate analyses, each value is the same percent of the mean as that listed for the corresponding constituent in table XVIII. For the ash analysis, each value is the same percent of the mean as that computed from the values listed for the ETF coal in table XVII. For the TiO_2 and P_2O_5, an average percent of the mean of 34 percent is assumed. The deformation, softening and fluid temperature values are from the ECAS study (table XVII).

(4) For the proximate and ultimate analyses, each value is the same percent of the mean as that listed for the corresponding constituent in table XIX. For the ash analysis, TiO_2 and P_2O_5 values, the same comments as in Note 3 apply. The deformation, softening and fluid temperature values are from the ETF study (table XVII).

(5) Assumed equal to the grindability of the primary coal.

per million Btu of heat input. This design sulfur content is the same as the design value specified in the ECAS study, and corresponds to the Macoupin County coals within 1.14 standard deviations of the mean value (table XVIII).

Under the June 1979 NSPS regulations, an SO_2 removal efficiency of not less than 90 percent is required for the design coals. A 90 percent removal efficiency reduces the maximum expected emissions from the stack to 0.83 lbs SO_2/million Btu. As this is lower than the 1.2 lbs per million Btu limit set by the standards, it will probably also be accepted by the EPA as meeting the Best Available Control Technology (BACT) regulatory requirements.

A2.0 ON-SITE CALCINATION PROCESS VERSUS PURCHASED LIME

Overall SO_2 emissions from the ECAS power plant were determined to be 0.86 lb/10^6 Btu heat input or an 88 percent reduction of the uncontrolled emissions. This includes steam boiler emissions of 0.747 lb/10^6 Btu (an 89 percent reduction), and the uncontrolled emission of 7.23 lb/10^6 Btu heat input from the coal burned for the on-site calcination process.

Question: Should the on-site calcination process be retained or should the purchase of lime be considered?

A2.1 Summary and Conclusions

It is concluded that neither on-site calcination, which is included in the ECAS study, nor the purchase of lime need be included in the reference plant design. Instead, direct utilization of limestone should be adopted. Lime is the preferred or required absorbent in dry scrubbing and systems where very high removal efficiencies are required. However, limestone systems in operation have demonstrated efficiencies of 90 percent and higher with high sulfur coals. Direct utilization of limestone is economically more attractive than utilization of lime in most cases where both absorbents can be used. Utility preference for limestone systems over lime systems supports this selection. About 77 percent of the new SO_2 scrubbing capacity planned in the United States is reported to use limestone (Ref. A10).

A2.2 Discussion

The question posed in the assessment task assumes that the plant SO_2 emission includes "the uncontrolled emission of 7.23 lb SO_2/10^6 Btu heat input from the coal burned for the on-site calcination process." However, overall SO_2 emissions are not affected by on-site calcination in a direct-fired rotary kiln such as that included in the ECAS study (Ref. A1). The coal fuel is burned in the presence of the lime product which effectively captures any sulfur dioxide produced. Figure 10 schematically illustrates a typical fuel feed and burner configuration for a direct-fired

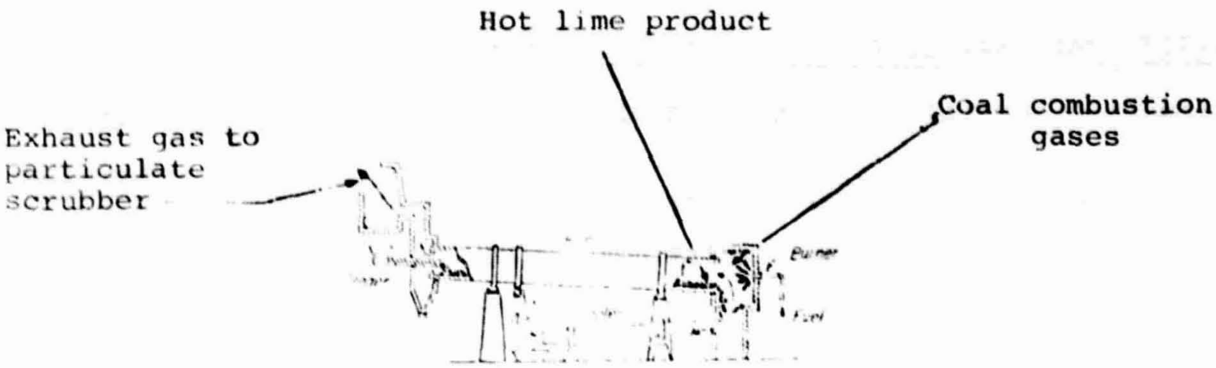

Figure 10. - Schematic Representation of a General Coal-Fired Rotary Kiln Illustrating the Fuel-Burner Arrangement (Ref. A8).

rotary kiln. It indicates that the coal combustion gases pass directly over the hot lime product.

Emissions from a direct-fired calciner, considered as a separate facility from a steam generating plant, are covered by Subpart HH--Standards of Performance for Lime Manufacturing Plants--June 1979 NSPS (Ref. A9). That subpart limits the emission of particulate matter from a calciner to 0.03 lb/ton of limestone feed, and the opacity of any atmospheric discharge to 10 percent. Since no sulfur dioxide is released, no requirement for calciner exhaust gas sulfur dioxide scrubbing is included in the standards.

To provide the necessary particulate emission control, a fabric filter can be included to scrub the exhaust gases. This is basically the configuration employed in the ECAS study. Since on-site lime production is not included in the Reference Plant, for the reasons discussed in the following paragraphs, control of calciner emissions is not considered further.

To determine whether to include on-site calcination or purchase off-site manufactured lime in the Reference Plant design, two alternatives are considered: produce lime on-site or purchase lime off-site. Both assume SO_2 scrubbing with lime. A third alternative is also possible, however - utilization of pulverized limestone directly. All three alternatives are schematically illustrated in figures 11a, 11b and 11c.

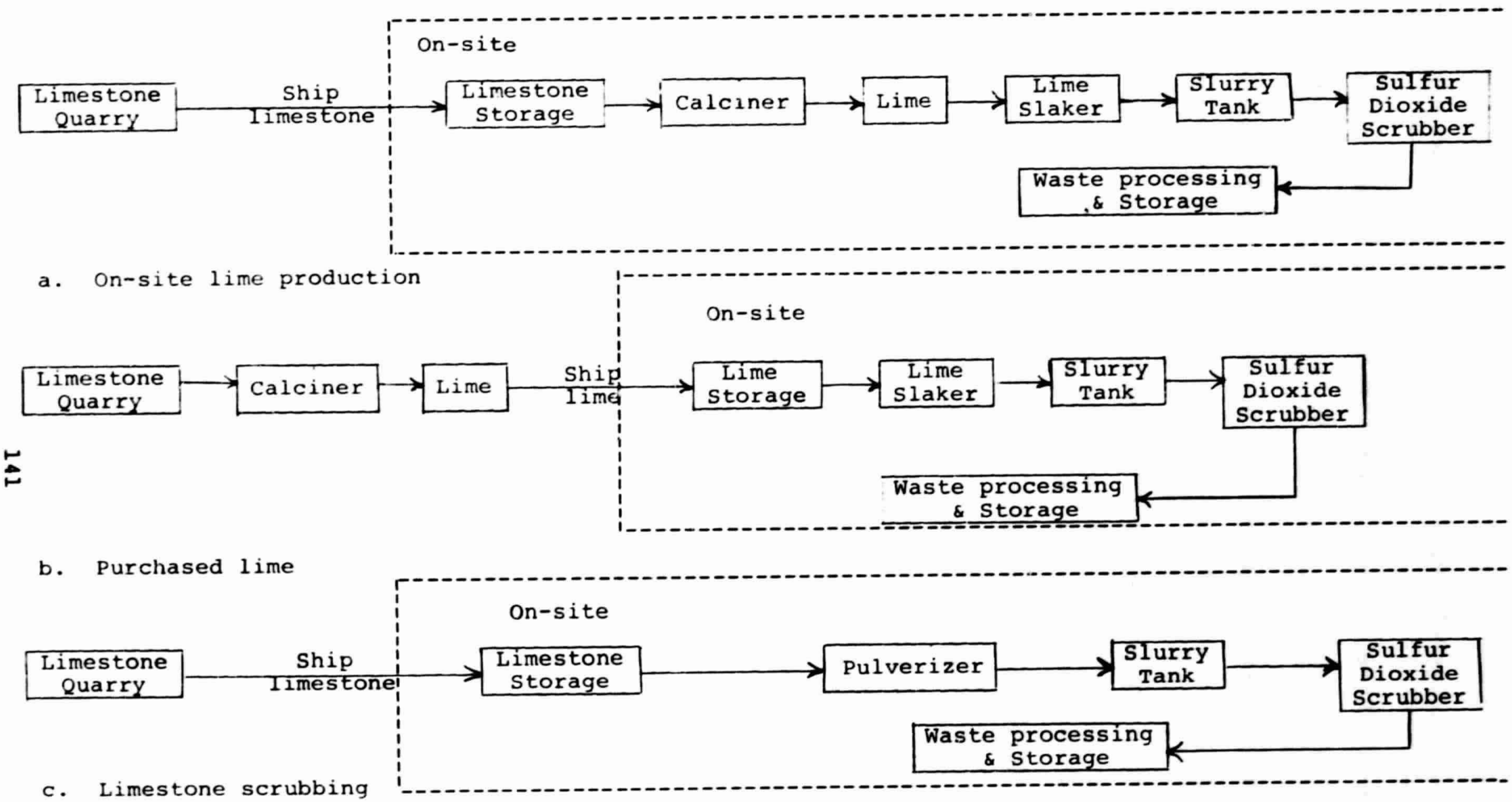

Figure 11. - Schematic Illustrations of Lime-Limestone Alternatives for Sulfur Dioxide Scrubbing System.

In the first alternative, limestone is purchased from a quarry and delivered to a storage area at the site. As needed, the limestone is reclaimed from storage, pulverized and calcined to produce lime which is slaked and fed as a slurry to the sulfur dioxide scrubber. Wastes from the scrubber, along with other plant wastes, are processed and stored on-site. In the second alternative, the processes of limestone quarrying and calcining are carried out off-site by a lime manufacturer and lime is delivered to the site where it is stored under cover. As needed, the lime is reclaimed from storage and, as in the first alternative, it is slaked and fed as a slurry to the sulfur dioxide scrubber. Wastes from the scrubber, along with other plant wastes, are again processed and stored on-site. In the third alternative, limestone is purchased from a quarry and delivered to the site. As needed, the limestone is reclaimed from storage, pulverized and fed as a slurry to the sulfur dioxide scrubber. Wastes from the scrubber, along with other plant wastes, are processed and stored on-site.

To provide some insight into the comparative attractiveness of the alternatives, table XXI lists qualitative differences between the major cost components of each, using the on-site lime production alternative as a reference. Where costs are noted, they are based on values reported in the ECAS study (Ref. A1) as of mid-1975. A current detailed economic analysis was not possible as it was beyond the scope of the task.

Item 1 compares the costs of limestone delivered to the site for Alternatives A, B and C. Alternatives A and C, which employ limestone feedstock and limestone scrubbing reagent, respectively, are listed as having the same cost per ton. Since Alternative B does not employ limestone, no cost is shown for it. As stated in the ECAS study, the cost of limestone delivered to the site, as of mid-1975, is $5/ton (Ref. A1, p. 87).

Item 2 lists the comparative costs of the scrubbing reagent (lime or lime equivalent) per ton of reagent for the alternatives. A reference cost of about $22/ton of on-site manufactured lime is

TABLE XXI. - QUALITATIVE COMPARISON OF COSTS FOR LIME/LIMESTONE ALTERNATIVES FOR SULFUR DIOXIDE SCRUBBING SYSTEM BASED ON MID-1975 DATA PRESENTED IN THE ECAS STUDY (REF. A1)

Item	Alternative A On-site lime production	Alternative B Purchased lime	Alternative Limestone Scrubbing
1. Cost of limestone per ton of limestone f.o.b. site	base (1)	NA (2)	Same as base (1)
2. Cost of scrubbing reagent ($/ton of lime or lime equivalent)	base (3) (lime)	70 percent of base (4)(lime)	45 percent of base(5)(limestone)
3. Reagent storage and handling	base (limestone storage)	about the same as base (lime storage)	about the same as base (limestone storage)
4. Limestone pulverizer	base	NA	slightly greater than base
5. Lime slaker	base	same as base	NA
6. Slurry tank	base	same as base	slightly greater than base
7. Sulfur dioxide scrubber	base	same as base	slightly greater than base
8. Waste processing and storage	base	same as base	slightly greater than base
9. Overall cost	base	slightly less than base	significantly less than base

(1) \$5/ton of limestone as quoted in the ECAS study (Ref. A1, p. 87).
(2) Not applicable/not required.
(3) Approximately \$22/ton of lime as calculated in table XXII.
(4) \$15.50/ton of lime scaled from \$5/ton of limestone by the lime/limestone price ratio, 3.1, determined in table XXIII from price quotations during May-June 1978.
(5) Approximately 2 tons of limestone are equivalent to 1 ton of lime in scrubbing capability. The cost of the lime equivalent is \$10/ton.

indicated for Alternative A in Note 3 of table XXI. This cost is calculated in table XXII, based on mid-1975 costs reported in the ECAS study. The calculation includes the contributions of the major expense items such as investment capital for the limestone handling equipment, and its installation, (levelized over a 30 year life starting in mid-1975, at a 10 percent interest rate); cost of limestone at a nominal consumption of 1300 tons/day, 237 days/year (assuming a plant capacity factor of 0.65); cost of coal for kiln firing (at $\$1/10^6$ Btu); and combined cost of maintenance and operation, energy for auxiliaries and waste disposal (estimated to be 10 percent of the annual capital plus fuel costs). The total annual cost of the lime produced is divided by the nominal annual number of tons of lime produced (assuming production of 652 tons/ day, 234 days/year) resulting in the $22/ton figure.

The value of the levelized capital cost in table XXII, Item 6, requires a brief note. The combined cost of the lime system (table XXII, Item 2) quoted in the ECAS study is used to calculate the levelized cost. The combined cost is a figure which includes the costs of the lime conveyor, bucket elevator, storage silos and lime slaker. The costs for the individual components could not be separated. A reduced value of levelized capital cost was therefore computed by neglecting charges for taxes, insurance and return on investment to compensate for the inability to add, in a consistent manner, the costs of the lime conveyor, bucket elevator, storage silos and lime slaker to Alternative B, which also includes these items on-site. The reduction may amount to as much as a 40 percent decrease in levelized capital cost (i.e., decrease of capital recovery factor from 0.18 to 0.10608) and therefore as much as a $3.30/ton reduction in the cost of the on-site produced lime, and is considered to be conservative for purposes of the present evaluation.

The cost of lime was not reported in the ECAS study, since purchased lime was not considered. Therefore an approximate cost for lime in the mid-1975 time-frame was developed for Alternative B

TABLE XXII. - APPROXIMATE COST OF PRODUCING LIME ON-SITE, BASED ON MID-1975 DATA PRESENTED IN THE ECAS STUDY (1)

Item	MH/Tons	Cost
1. Limestone handling equipment (p. 39)(2)	22,000MH	$1,250,000
2. Lime system (calciner with travelling gate kiln; kiln stack; coal conveyor, bucket elevator and storage bin for kiln; lime conveyor, bucket elevator a d storage silos; lime slaker)(p. 40)	66,000MH	3,660,000
3. Subtotal	88,000MH	$4,910,000
4. Direct and Indirect labor cost ($11.75 + $10.56 per MH)(p. 33)		1,965,000
5. Total capital cost as of mid-1975 (3)		$6,875,000
6. Levelized capital cost per year (30 yr life, mid-1975 startup, 10 percent interest rate; CRF = 0.10608)		729,300
7. Nominal tons of limestone used per year (1300 tons/day, 237 days/yr)(p. 16)	308,100	
8. Cost of limestone used per year @ $5/ton (p. 87)		1,540,500
9. Nominal tons of fuel used for calcining per year (174 tons/day, 237 days/yr)(p. 15)	41,238	
10. Cost of fuel used for calcining per year @ $21.60/ton ($1/10^6 Btu)(p. V)		890,740
11. Cost of lime produced on-site per year (excluding M&O, auxiliary energy and waste disposal)		$3,160,540
12. Approximate M&O, auxiliary energy and waste disposal costs @ 10 percent of annual capital plus fuel costs		162,000
13. Total annualized cost of lime produced on-site		$3,322,540
14. Nominal tons of lime produced on-site per year (650 tons/day, 237 days/yr) (p. 16)	154,050	
15. Cost per ton of lime produced on-site as of mid-1975		$ 22

(1) Reference A1.

(2) Page numbers in parentheses refer to the pages in the ECAS study (Ref. A1) where the data used to derive the operating quantities/costs may be found. 237 days/yr is based on a 65 percent plant capacity factor.

(3) No contingency, escalation or interest during construction is included, since the process is well known and it is expected that the system can be erected within one year.

in table XXI by scaling the $5/ton cost for limestone, quoted in the ECAS study, by the ratio of lime to limestone cost developed from a Burns and Roe telephone survey of nine lime manufacturers carried out during May-June 1978. The results of the survey are summarized in table XXIII, where the ratio of the lime to limestone average price is calculated to be 3.1 to 1. Applying this ratio to the $5/ton cost of limestone results in the $15.50/ton delivered cost of lime indicated in table XXI. It should be noted that this analysis assumes that the escalated rates for the cost of lime and limestone are approximately the same during the 1975-1978 period. That is, it is assumed that the ratio of the cost per ton of lime to limestone in mid-1978 dollars ($39.60 and $13.05, respectively) is the same as in mid-1975 dollars ($15.50 and $5.00, respectively).

It should further be noted, that the costs of lime and limestone vary greatly throughout the country, and are very site specific. The costs depend not only on the transportation costs of shipping lime or limestone from the quarry to the user, but also upon the costs of producing lime or limestone at each quarry.

The cost of the purchased lime for Alternative B is therefore about 70 percent of the base cost of the on-site manufactured lime for Alternative A. It should be noted, however, that this figure is based on the average value of a range of quoted prices. If the actual price is higher than $15.50/ton, the cost of Alternative B approaches that of Alternative A.

No lime costs are associated with Alternative C. However, the cost for the limestone required to provide a sulfur dioxide emission reduction equivalent to that produced by a ton of lime is about twice the per ton cost of limestone, since two tons of limestone are necessary to provide the same amount of calcium as in the lime. Therefore, the comparative cost of the limestone for Alternative C is noted to be about $10/ton or 45 percent of the base cost for Alternative A.

TABLE XXIII. - QUOTED PRICES FOR LIMESTONE AND LIME
DELIVERED TO A ST. LOUIS, MISSOURI SITE
MAY - JUNE 1978 (1)

Company	Quarry Location	Quoted Price $ Per Ton (2a,b)		Transportation ($/ton)	Lime/Limestone Price Ratio
		Limestone	Lime		
1. Westinghouse	Mississippi Lime Co.	9.00-12.00	35.00	3.00	3.9-2.9
2. Riverview Stone & Material Co.	Florissant, MO	6.35-6.60	NA(3)	3.00	-
3. Limestone Prod. Corp.	Sparta, NJ	27.90	NA	17.50	-
4. Concrete Co. of Springfield	Springfield, MO	10.25	NA	6.00-8.00	-
5. Marblehead Lime Co.	Pittsburgh Crystal, MO	16.00-18.00	52	6.00-8.00	3.25-2.9
6. Ash Grove Cement Co.	Springfield, MO	NA	49	13.35	-
7. Arkansas Lime Co.	Batesville, AR	6.50(4)	35(4)	NA	-
8. Mississippi Lime Co.	St. Genevieve, MO	11.75-15.25	33-33.50	1.75-2.25	2.9-2.2
9. Linwood Stone Products Co.	Davenport, IA	10.50	39.50	2.25(5)-3.00(6)	3.8
Average		13.05	39.60	-	3.1
Standard Deviation		6.5	7.80	-	0.6

(1) Based on a Burns and Roe survey of producers.
(2a) 1/8" x 0" particle size.
(2b) Including transportation except where noted.
(3) Not available.
(4) Transportation cost not included. Omitted from averages.
(5) Uncovered barge.
(6) Covered barge.

Item 3 compares the costs of on-site reagent storage. Greater storage and handling costs are associated with the additional precautions associated with handling and storing the lime in Alternative B. However, only about one-half the amount of lime compared to limestone is involved. Overall, therefore, the costs of the limestone and lime storage and handling systems are expected to be about the same, as indicated. Similarly, the storage and handling costs of Alternative C are anticipated to be about the same as that of Alternative A, although, slightly more limestone is expected to be required to account for the slightly lower scrubbing efficiency of limestone compared with lime.

Comparison of Items 1, 2 and 3 in table XXI leads to the conclusion that Alternative C is significantly less costly than the other two. Moreover, adding the cost components of Items 4-8 is not expected to alter this result. The costs of the equipment, associated piping and waste processing and storage for Items 4-8 of Alternative C are all estimated to be slightly greater than the corresponding costs for Alternatives A and B. This is due to the larger quantities of limestone that are required for the scrubber in Alternative C to achieve the same scrubbing efficiency as the lime processes in Alternatives A and B. However, it is estimated that the sum of the additional costs associated with these items will not be of a magnitude to overcome the 55 percent cost advantage over Alternative A or the 25 percent cost advantage over Alternative B. Based on cost, Alternative C is the most attractive.

In addition, a recent report on the status of flue gas desulfurization in the United States (Ref. A10) states that there is an increasing preference in the utility industry for the utilization of limestone over lime. This preference has been bolstered by the success of limestone systems in achieving 90 percent SO_2 scrubbing efficiency (Ref. A10), dispelling the concern that 90 percent efficiency might not be achievable using limestone. As of the beginning of 1979, for example, limestone systems constituted approximately 59 percent of the operating scrubbing capacity, 50 percent of the capacity under construction, and 77 percent of that planned. Also,

limestone quarries are available in most areas in the United States but lime manufacturing plants are less widely distributed.

Based on the foregoing considerations, Alternatives A and B, using on-site manufactured lime and purchased lime, respectively, were dropped, and the Reference Plant designed on the basis of Alternative C, utilization of limestone directly.

A3.0 REHEAT OF STACK GAS: METHOD--SELECTION PREFERENCE

In the ECAS steam plant, air, which has been indirectly heated with extraction steam, is blended with the combustion gas leaving the scrubber to reheat the gas before it enters the stack. This method of reheating the gas is inefficient compared to using a steam/flue gas heat exchanger. Using such a heat exchanger was rejected because of the corrosiveness of the flue gas at the temperature at which it would enter the heat exchanger.

Question: Should the indirect heating air blending method of stack gas reheat be retained? Reassess the reheat method including the possibilities of using a heat exchanger or a combination of heat exchanger and air blending.

A3.1 Summary and Conclusions

It is concluded that the indirect (steam-air) method of stack gas reheat used in the ECAS study is acceptable and should be retained in the reference plant design until more experience is gained with alternative methods being utilized in new installations. Two other alternatives recently initiated in development are waste heat recovery reheat and no reheat. The former provides the heat required for the indirect reheat method from energy in the combustion gases upstream of the air preheater rather than from steam. The latter requires no reheat energy, but does require a significantly larger stack compared to one with reheat. These alternatives may evolve into more attractive methods than the indirect method. However, insufficient information is available at this time on which to base a confident acceptance of either for the reference plant design. Table XXIV summarizes and compares the characteristics of the seven alternative stack gas reheat methods considered. The relative economic penalties of the energy losses associated with the different stack gas reheat methods are of course, important to their viability. The detailed study necessary to evaluate the economic penalties, however, was beyond the scope of this assessment.

TABLE XXIV. - COMPARISON OF STACK GAS REHEAT METHOD CHARACTERISTICS

Characteristic	Method of Reheat						
	In-line	Indirect	Combined indirect & in-line	Direct Combustion	Flue gas bypass	Waste heat recovery	No reheat
1. Energy source	Turbine extraction steam	Turbine extraction steam	Turbine extraction steam	Oil	Boiler exhaust gases	Boiler exhaust gases	None required
2. Reheat process	Steam to stack gas heat transfer	Steam to air heat transfer, air mixing with stack gas	Steam to air, heat transfer, air mixing with stack gas, followed by steam to stack gas heat transfer	Oil combustion heat generation and mixing with stack gas	Boiler exhaust gas to stack gas heat transfer	Boiler exhaust gas to air heat transfer, air mixing with stack gas	Not applicable
3. Major equipment required	Steam-stack gas heat exchanger	f.d. fans, steam-air heat exchanger, air-stack gas mixing chamber	f.d. fans, steam-air and steam-stack gas heat exchangers, air-stack gas mixing chamber	Oil burner with stack gas mixing chamber	Bypass ducting, exhaust gas-stack gas mixing chamber	f.d. fans, regenerative heat exchanger, ducting, air-stack gas mixing chamber	None
4. Reported problems	In-line component subject to corrosion & degradation	Inefficient utilization of boiler steam	In-line component subject to corrosion even though the initial indirect air heating is expected to reduce it somewhat	Employs a resticted resource	Does not permit compliance with June 1979 NSPS 90% scrubbing for high sulfur coal	Little information available with respect to long-term operating experience	Chimney liners subject to strong attack and degradation; little information available with respect to long-term operating experience
5. Acceptability of application to reference plant	Unacceptable; requires development and testing of more resistant materials	Acceptable (1)	Unacceptable; requires development and testing of more resistant materials	Unacceptable based on national priorities	Unacceptable based on NSPS compliance requirement	Unacceptable due to lack of sufficient information; requires testing (2)	Unacceptable due to lack of sufficient information; requires testing (2)

(1) Recommended for inclusion in reference plant.
(2) This method shows promise and may develop into a more attractive one than the method recommended for the reference plant. As experience is gained employing the method, its detailed economics, which are beyond the scope of this assessment, will determine its ultimate attractiveness.

A3.2 Discussion

Reheat methods include: (1) In-line (direct steam-flue gas heat exchange), (2) Indirect (steam-air-stack gas heat exchange), (3) Combined indirect and in-line, (4) Direct combustion (using oil), (5) Flue gas bypass, (6) Waste heat recovery (combustion gas-air-stack gas), and (7) No reheat (wet stack).

Direct combustion with oil is not in accordance with the Fuel Use Act and national policy to reduce the use of oil, and would be relatively expensive in view of the anticipated price of oil in the future. This method was therefore eliminated. Method 5, flue gas bypass, would require separate treatment of the bypass gas before discharge to the atmosphere. This method was therefore also eliminated. Five remaining reheat options are considered consequently for application to the reference plant; in-line, indirect, combined in-line and indirect, waste heat recovery, and no reheat.

Historically, in-line reheaters in wet SO_2 scrubber systems have been susceptible to corrosion and solids deposition. This has been attributed to inefficient operation of the upstream scrubber mist eliminator. Developers at some test facilities have found, however, that the corrosion problems could be controlled by employing more expensive high alloy materials such as 316 and 316L stainless steels to fabricate the reheat bundles. These materials have been noted to provide smoother mating surfaces, which reduce the occurrence of crevices that can act as sites for build-up of the corrosive agents, and higher molybdenum content, which increases the resistance to localized pitting and crevice formation. As a consequence, in systems where minimization of energy usage is of prime importance and an in-line system is felt to be a necessity, it has been suggested that to reduce cost, the reheat system be divided into high alloy and carbon steel sections. The more expensive high alloy section would be employed just downstream of the SO_2 scrubber, where moisture condensation and acidic attack would be most likely to occur. This section would provide initial superheat of the flue gas to prevent any additional condensation further downstream where the less expensive carbon steel would be employed.

Some success with this approach has been reported, but more time and testing is necessary to prove its reliability under all conditions. Since reliability is a primary utility concern, the trend in the industry has been to avoid the use of in-line systems entirely and opt for indirect reheat. Based on this trend and the unresolved materials problems, use of in-line components in the reference plant is not recommended, and in-line reheat or a combination of in-line and indirect reheat is eliminated leaving indirect, waste heat recovery, and no reheat as the remaining possible alternatives.

The waste heat recovery alternative is a recent development which is similar to the indirect reheat alternative. It is based on the fact that if all or part of the reheat air energy can be supplied from a point in the plant cycle with heat of lower grade than the turbine extraction steam which is used in indirect reheat, more efficient plant operation will result. Based on the values presented in figure 2 of the ECAS study (Ref. A1, p. 6), a 350° F (450° K) (or greater) source would be required for the reference plant. This source would be sufficient to raise the temperature of the reheat air from 59° to 334° F (288° to 441° K) to provide a final stack gas temperature of 250° F (394° K) after mixing with the stack gas leaving the sulfur dioxide scrubber.

An appropriate point in the plant cycle for the reheat air energy source would be just upstream of the air preheater where the heat in the combustion gas at 740° F (666° K) (Ref. A1, p. 11) could be employed. The heat would be transferred in a regenerative heat exchanger to minimize the effects of the corrosive components of the combustion gas.

Although this technology is promising for the future, only two plants employing it were in the planning stage at the time of this study (Ref. A10). As a result, little information was available with respect to its impact on the air preheater design, operation and cost, operating temperatures downstream of the air preheater, boiler efficiency, and on the overall reliability of the plant. Acceptance of the technology for inclusion in the reference plant

design could not be made with confidence. The use of waste heat recovery reheat was therefore, eliminated from further consideration leaving the methods of indirect and no reheat as the remaining possible alternatives.

The no reheat alternative is another recent development. Its attractiveness is obvious, since it eliminates the need to divert any energy from the power cycle. No reheat, however, requires a significant modification of the exhaust stack configuration and materials compared to a stack preceded by reheat. For example, to prevent precipitation of acidic vapor in the atmosphere external to the stack, the flow entering the stack is slowed by enlarging the stack diameter by 20 percent. This allows the flue gas more time to cool and the vapor it contains more time to condense on the stack walls. The condensate then drains to a pool at the bottom where it is collected for disposal. The inner wall of the stack must be lined with protective acid resistant brick or resistant liner, which is subject to deterioration at a rate which is not known at present. In addition, in some cases, the height of the stack must be increased over that of a stack preceded by reheat to provide the buoyancy required for dispersion of cooler, less buoyant effluent gas.

Although a few plants have been built employing no reheat, they have all included a provision for reheat should it become necessary. This is indicative of the current lack of confidence in the long-term reliability of the alternative. Similar to waste heat recovery, though, the technology is promising for the future. However, little information is available on which to base a confident acceptance of it for the reference design. Therefore, the use of no reheat was eliminated in favor of the indirect reheat alternative presented in the ECAS study.

A4.0 EFFECT OF SULFUR DIOXIDE SCRUBBER ON PARTICULATE EMISSIONS

The ECAS report is unclear about the effect of the scrubber on particulate emissions. The particulate emissions figure given, 0.092 lb/10^6 Btu heat input, appears to be the particulate level leaving the electrostatic precipitator (ESP) and entering the scrubber. (This figure may be obtained from the assumed ash removals: 25 percent of the total ash upstream of the ESP and 98.6 percent removal efficiency in the ESP. The 98.6 percent ESP efficiency and the final ash of 0.75 percent of the total given on page 7 of the ECAS report (Ref. A1) are inconsistent. The 0.75 percent figure corresponds to an ESP efficiency of 99 percent). The report states that some of the particulate matter remaining in the flue gas after it leaves the ESP will be washed out in the scrubber. A demisting spray just before the gas leaves the scrubber is intended to minimize carryover from the scrubber, but the effectiveness of the method for removing particulate matter is not given.

Question: What is the effectiveness of the scrubber on particulate emission? Examine the effectiveness in light of the more stringent June 1979 EPA New Source Performance Standards for particulate emissions.

A4.1 Summary and Conclusions

The effectiveness of currently available mist eliminators is actively under industry study. Chevron and baffle-type configurations are increasing in popularity, but require further long-term testing. At the time the June 1979 NSPS were promulgated, the EPA indicated that they were of the opinion that the effectiveness of mist eliminators in removing particulates was adequate (Ref. A11), but the data available were not conclusive. From measurements of liquid-only applications, the overall collection efficiency of chevron and baffle-type mist eliminators was estimated to be 85-90 percent for particles 10 micrometers and larger (Ref. A13). Acid mist carryover (not containing particulates) was considered to be a problem only insofar as accurate monitoring of particulate emissions was concerned. However, acid mist carryover created by the

emission of moisture and the residual SO_2, SO_3 and NO_x allowed by the June 1979 NSPS, and not currently subject to the particulate emissions limitation, may be restricted in the future. For example, the EPA has recently proposed (Ref. 14, pp. 51937-8) that a major emissions source (such as the reference coal-fired plant) which emits more than 1 ton of sulfuric acid mist per year, the de minimis (or insignificant) level, be subject to EPA approval and that best available control technology be employed in the plant design. In addition, if the source exceeds the 1 $\mu g/m^3$ 24-hour ground level sulfuric acid mist de minimis level, a detailed ambient air quality analysis would be required. The method of measuring the sulfuric acid mist emissions still remains indefinite, however. To meet these sulfuric acid mist restrictions, additional stages of mist elimination may be required to achieve the desired effectiveness. If this turns out to be the case, improved mist eliminator effectiveness will be achievable probably only with an accompanying increase in system pressure drop and operating and maintenance costs. Nevertheless, improvements in mist eliminators are expected to be achieved with further research, design and development. The mist eliminators included in this study, or modifications of them, are expected to provide adequate particulate and acid mist collection to meet the June 1979 NSPS.

As noted in section A4.0, the second paragraph on page 7 of the ECAS report (Ref. A1) contains some numerical inconsistencies concerning particulate removal in the ECAS reference plant. In particular, it states that, "The electrostatic precipitator with an efficiency of 98.6 percent, collects another 75 percent of the total ash, leaving only 0.75 percent in the gas flow to the wet scrubbers." This statement, to be consistent with numbers presented later in the ECAS report, should read, "The electrostatic precipitator, with an efficiency of 98.6 percent, collects 98.6 percent of the remaining ash, leaving only 1.05 percent in the gas flow to the wet scrubbers."

In addition, several other numerical inconsistencies were detected in a few of the process diagrams and charts presented in the ECAS report. They were investigated so that their origins could be understood, their orders or magnitude determined and their possible impact on the design of the modified Reference Plant estimated - at least qualitatively. The impacts of the inconsistencies on the economics of the ECAS study and the design of the modified plant appeared to be small. A detailed check and evaluation of all the ECAS reference plant design parameters was required to ascertain the precise magnitude of correcting these inconsistencies. Such a check and evaluation, however, was beyond the scope of this assessment.

The June 1979 NSPS (Ref. A11) states that measurements of plant particulate emissions to confirm compliance with the EPA particulate emission limit (0.03 lb/10^6 Btu heat input) may be taken upstream of a wet SO_2 scrubber, because errors can be introduced by the interaction of acid mist carryover with the available measuring equipment. However, this is acceptable only if particulate carryover from the scrubber is minimized by the use of an effective mist eliminator at the outlet of the scrubber. A review of the EPA standards (Ref. A12) that applied at the time of the ECAS study indicates that measurements for compliance testing could not be taken at a point upstream of the SO_2 scrubber in the ECAS reference plant. Test measurements were required at the stack, making effective particulate and mist elimination more critical. This problem is not addressed in the ECAS report.

A4.2 Discussion

The ECAS report is unclear with regard to the expected level of particulate concentration at several points in the reference plant process flow. Confusion is created to some extent at three places in the report: (a) the second and third paragraphs on page 7; (b) the specification of the waste stream values in figure 4 -- Conventional Steam Plant Flow - 860 MW_e (page 11); and (c) the process flow charts associated with the Process Flow Diagram of figure 7

(page 15). The first item (a) is discussed in the following paragraphs, the second and third items (b) and (c) were considered in detail but are not discussed, since they were found not to have a significant effect on the results of either the ECAS study or this study. There may be other inconsistencies in the ECAS reference plant process flows. A detailed check and evaluation of all the ECAS reference plant design parameters would be required to make certain that they do not significantly impact the investment costs of the reference plant. A review, to locate and resolve the inconsistencies, was outside the scope of this assessment. Only the three inconsistent items noted before were checked.

The second paragraph on page 7 of the ECAS study states:

> "Slag is removed from the boiler furnace beneath the firing zone, fly ash from a hopper just before the air preheater. These solids representing 15 and 10 percent of the total ash, respectively, are sluiced to the sludge pond. The electrostatic precipitators, with an efficiency of 98.6 percent, collect another 75 percent of the total ash, leaving only 0.75 percent in the gas flow to the wet scrubbers."

The phrase "collect another 75 percent of the total ash, leaving only 0.75 percent...," is inconsistent with the remainder of the paragraph. The following revised, expanded and more consistent form of the statements is recommended as being more precise:

> Slag is removed from the boiler furnace beneath the firing zone, fly ash from a hopper just before the preheater. These solids, which represent 15 and 10 percent by weight (25 percent combined) of the total ash, respectively, are sluiced to the sludge pond. This leaves 75 percent (wt) of the total ash (as dust) remaining in the gas flow to the electrostatic precipitators. The electrostatic precipitators, with an efficiency of 98.6 percent, remove 98.6 percent (wt) of this remaining dust leaving only 1.05 percent (i.e., 0.75 x (1 - 0.986) x 100) of the total ash in the gas flow to the SO_2 scrubbers. (The remaining part of this paragraph extends

the original ECAS statements for completeness). This represents an overall plant solid waste (bottom ash plus fly ash) removal efficiency of 98.95 percent (i.e., (1 - 0.0105) x 100) up to, but not including, the SO_2 scrubber. Noting that the total ash is 9.6 percent of the coal fired (Ref. Al, p. 85), that the coal firing rate is 730,570 lb/hr (Ref. Al, p. 29) for 100 percent operation (250° F (394° K) stack temperature), and that the coal heat value is assumed to be 10,788 Btu/lb (Ref. Al, p. 2), the particulate loading of the gas flow entering the SO_2 scrubber is 736 lb/hr (i.e., 730,570x0.096x0.0105), which is about 1.8 percent greater than the value of 723 lb/hr listed on page 15 (upper chart), and the relevant particulate emission parameter is 0.093 lb/10^6 Btu heat input (i.e., 736 x 10^6/(730,570 x 10,788)), which is about 1.1 percent greater than the value of 0.092 lb/10^6 Btu heat input listed in table 20 (page 48).

As can be concluded from the ECAS report, therefore, the flow entering the SO_2 scrubber more than meets the ECAS study 0.1 lb/10^6 Btu heat input particulate emission limit.

The effect of the scrubber on the fly ash particulates referred to in the assessment definition is incompletely considered in the third paragraph on page 7 of the ECAS report. This paragraph states that "The remaining fly ash will be washed out of the flue gas... (by the scrubber)." It is a fact that additional particulate removal will occur to some extent in a well designed scrubber. However, for design purposes, the percent reduction allowable for assessing compliance with the June 1979 NSPS is subject to EPA approval. For example, the EPA has recently allowed credit to be taken for removal of 80 percent of the remaining particulates entering a wet SO_2 scrubber for a proposed plant in Louisiana (Region VI). Whether this allowance will be acceptable for all regions of the country is not known at the present time.

On the other hand, carryover of entrained particles of lime (or limestone) and calcium sulfates in the scrubber gas outlet is expected

to offset the fly ash reduction. The extent to which the offset occurs is only indirectly referred to in the ECAS report by the statement that "Carryover of the slurry and lime are avoided... (with a demisting spray at the scrubber exit)." According to the discussion in the preamble to the June 1979 NSPS, particulate carryover is not expected to be a problem, as illustrated by the following quote, "...overall particulate matter emissions, including sulfate carryover, are not increased by a properly designed, constructed, maintained and operated FGD (flue gas desulfurization) system" (Ref. All, page 33585). It should be noted that the quote does not indicate that the particulate emissions are expected to be reduced overall. It also must be recognized as being based only on data that were available at the time the June 1979 standards were promulgated. At that time, few SO_2 scrubbing systems designed to meet the 0.03 $lb/10^6$ Btu heat input particulate emission limits were in operation. Additional long-term testing is still required.

For design purposes, a reasonably conservative assumption for the particulate emissions from the wet SO_2 scrubber is that they are not significantly affected by the scrubber. The extent to which this is true, however, still continues to be under study. The effectiveness of a wet scrubber to reduce or at least leave the particulate emissions unchanged depends on the effectiveness of the scrubber mist eliminator.

Mist eliminators are actively under development, test and evaluation. Chevron and baffle-type configurations are the predominant geometries employed in the U.S.A. (Ref. A10). It has been estimated, based on application of similar collectors in other industries, that the collection efficiencies of chevron and baffle collectors are 85 to 95 percent for particles 10 micrometers and larger. Other geometries, such as wire mesh and gull wing also have been tested. Alternatively, an electrostatic collection technique has also been tried. Based on industry trends, the chevron and baffle-type configurations appear to be preferred. These configurations provide simplicity and flexibility, relatively low

pressure drop, easy access for maintenance and appear to have adequate particulate collection efficiencies to meet the June 1979 NSPS requirements.

Multiple stages have been found to be required for effective collection efficiency in many cases. This is accompanied by a slight increase in pressure drop. The number of stages required has also been found to be process sensitive, depending on whether lime or limestone is employed. Lime, for example, exhibits a greater reactivity than limestone, has a greater utilization and results in fewer unreacted particles to be entrained. As a result, a one-stage mist eliminator may be sufficient for a scrubber employing lime. On the other hand, a two- to three-stage mist eliminator may be necessary for a scrubber employing limestone.

The overall collection efficiency of chevron and baffle-type mist eliminators depends on particle size distribution of the mist, pressure drop, gas velocity, cleanliness of surface, and liquid-to-gas (L/G) flow rate. As the scrubber L/G ratio increases, the average particle size generated in the scrubber decreases. As a result, the minimum velocity at which reentrainment occurs becomes lower and the overall mist eliminator collection efficiency goes down. Similarly, as the gas velocity through the mist eliminator is increased, the average particle size decreases, decreasing the overall collection efficiency. Thus, the greater primary collection efficiency that might be expected to result from design for higher velocities (greater particle inertia) is offset by the decreased collection efficiency of smaller particles.

Historically, mist eliminators have been susceptible to corrosion. Most suppliers now recommend the use of fiberglass reinforced plastics, polypropylene and corrugated plastics in place of stainless steels or other alloys. These nonmetallic materials are relatively lightweight, not too expensive, not susceptible to corrosion, and provide adequate resistance to high temperature excursions (Ref. A10).

Some investigators have stated that mist eliminators provide effective separation of particulates entrained in liquid droplets from the gas flow in the wet SO_2 scrubber exhaust stream. However, because of the added complexity that solids add to the determination of mist eliminator efficiency, the measurement of performance of mist eliminators following wet SO_2 scrubber systems has been unreliable. Additional testing is needed to confirm their long-term reliability. Credit for particulate collection by mist eliminators, therefore, must be taken conservatively.

Mist eliminators also provide acid mist removal from the flow to some extent. However, the acid mist removal is not complete and affects the accuracy of the measurement of the particulates in the exhaust stream by the methods recommended in the June 1979 NSPS (Ref. All, pgs. 33608-33609). Thus, the June 1979 NSPS (Ref. All) states that due to these errors, compliance with the NSPS may be determined by measuring the particulate emissions present in the flow between the outlet of the particulate matter control devices (the electrostatic precipitator in the case of the modified reference plant) and the inlet to the wet SO_2 scrubber. The June 1979 NSPS further states that this location for measurement of particulate emissions will remain applicable until a more acceptable method than those currently available for measuring particulate emissions in the exhaust stream of a wet scrubber is developed. In light of the June 1979 NSPS, therefore, the observation that the particulate emission value listed in the ECAS report (table 20, page 48, for example) represents the emissions leaving the electrostatic precipitator and entering the SO_2 scrubber is in compliance with current EPA practice, although the value of 0.092 lb $SO_2/10^6$ Btu heat input exceeds the 0.03 lb $SO_2/10^6$ Btu heat input 1979 NSPS requirement by a considerable margin. However, based on the standards in effect at about the time of the ECAS study (see for example, Ref. A12, paragraphs 60.46(a) (3), 60.46(b), App. A - Methods 1 and 5) the measurement of particulate emissions should have been referred to the exit of the SO_2 scrubber, and not the exit of the electrostatic precipitator, since the recommended measurement techniques at the

time required measurements downstream of the scrubber when the scrubber was located downstream of the particulate collector.

A5.0 CONTROL OF NITROGEN OXIDES

There does not seem to be any justification for the quoted NO_x emission level given in the ECAS report. The method of control is stated to be staged combustion.

Question: Is the staged combustion method of NO_x reduction capable of meeting the more stringent June 1979 EPA NSPS NO_x reduction standard? A detailed NO_x analysis using current and proposed available control techniques will be made.

A5.1 Summary and Conclusions

Based on the information available at the time of promulgation of the June 1979 NSPS, and on the information that has become available since then, methods of NO_x control are available to meet the 0.6 lb $NO_x/10^6$ Btu heat input emission limit specified. These methods (see, for example, Ref. A11, pages 33585-7), applied separately or in combination (where possible), include staged combustion, reduction of excess air, reduction of heat release rate and use of low-emission burners. Staged combustion is not singled out in the June 1979 NSPS as the primary method of NO_x control, as was done in the ECAS report (Ref. A1). However, in all likelihood, staged combustion, or a variant of it (such as turning down the fuel flow to upper combustor burners, increasing it to lower ones and at the same time increasing the airflow to upper burners), would have provided sufficient NO_x control to meet the less restrictive 0.7 lb $NO_x/10^6$ Btu heat input specified for the ECAS study (Ref. A1). It is of note that none of the methods of NO_x control mentioned requires any variation of the configuration of the ECAS reference plant to provide compliance with the June 1979 NSPS. All variations are internal to the boiler furnace and, in most cases, are not expected to affect boiler overall performance.

The factors on which NO_x generation depend are basically the fuel-bound nitrogen content, combustion temperature and availability of excess air (i.e., oxygen). Other than selecting a fuel with a low nitrogen content, little can be done to alter the first of these

factors. The second and third, on the other hand, can be adjusted to minimize NO_x generation.

The second factor, combustion temperature, involves control techniques to maintain a firing temperature below about 2800° F (1811° K). Above this temeprature, thermal NO_x formation is enhanced, due to more efficient reaction of the nitrogen and oxygen in the air alone. Among the temperature control techniques are two-stage combustion, removing one or more burners from service, increasing the combustion zone size and installing low-NO_x burners. These methods can potentially reduce NO_x formation by anywhere from 20 to 60 percent, depending on the fuel used. In some situations, however, use of these techniques requires a boiler derate, so careful evaluation is necessary before their application.

The third factor, control of excess air, has a limited effect on NO_x emissions. There is a practical lower limit below which combustion becomes incomplete and combustion efficiency is degraded. This limit is in the range of 7 to 10 percent excess air (corresponding to 1.5 to 2 percent excess oxygen) as compared to previously accepted power plant practice of employing 15 to 20 percent excess air (corresponding to 3 to 4 percent excess oxygen) for greater flame stability and assures completeness of combustion. In addition to reducing NO_x emissions, reducing excess air is attractive since it reduces stack losses and the capacities of the forced draft and primary air fans and increases boiler efficiency.

Along with the techniques that control NO_x during the combustion process, flue gas treatment techniques, which treat the combustion gases downstream of the boiler, are receiving considerable attention. These techniques are expected to provide the levels of NO_x reduction required to meet the lower emission limits expected in the future. A few methods are currently under development which reduce NO_x emissions by injecting ammonia into the flue gas in the presence of a catalyst. Depending on the specific catalyst and reactant concentrations employed, NO_x emissions have been claimed to be reduced up to 90 percent (Ref. A19). Although these methods are highly promising, they are at the frontiers of combustion technology and will require

more evaluation and study before achieving general acceptance by the utility industry.

A5.2 Discussion

A5.2.1 NO_x Emission Limit Considerations

The June 1979 NSPS NO_x emission limit for coal combustion is based principally on the results of EPA testing performed with six electric utility boilers. These boilers were representative of current boiler designs and burned a variety of bituminous and subbituminous coals (Ref. A11). The results of the testing indicated that the most effective techniques for NO_x control were staged combustion (as referred to in the ECAS report, Ref. A1), reduced heat release rate, and reduced excess air. Specially designed low-emission burners were also found to be effective in controlling NO_x levels.

In addition to the experimental test program, the EPA also considered statements made by the major manufacturers regarding their ability to design equipment to meet the proposed NO_x standard. One manufacturer guaranteed that its new boilers would meet, without adverse side effects, the 0.6 lb $NO_x/10^6$ Btu heat input emission limit proposed, and two others guaranteed that their new boilers would not only meet the 0.6 lb $NO_x/10^6$ Btu heat input limit, but would also meet the more restrictive 0.45 lb $NO_x/10^6$ Btu heat input State of New Mexico emissions limit (Ref. A11).

Furthermore, the data available at the time that the 1979 NO_x standards were initially proposed, indicated that NO_x emission levels below 0.5 lb $NO_x/10^6$ Btu heat input were achievable with a variety of coals burned in boilers made by the major manufacturers. Even lower levels were considered to be achievable by employing flue gas treatment--injecting ammonia into the flue gas stream in the presence of a catalyst. However, since ammonia injection was not adequately demonstrated on full-size utility boilers at the time of promulgation of the 1979 NSPS, it had only minimal influence on the NO_x standards.

Several utilities and boiler manufacturers indicated concern that accelerated boiler tube corrosion might occur during low-NO_x operation. The severity of the corrosion was expected to vary with the coal sulfur content. Corrosion during the combustion of high-sulfur bituminous coal was expected to be particularly aggravated, due to the presence of the reducing atmosphere that is sometimes associated with low-NO_x operation. However, based on the data obtained during the EPA testing, indications were that tube corrosion did not significantly increase during low-NO_x operation. These results could not be considered conclusive since the testing was carried out over relatively short periods of time (30 days maximum), and in one case, the boiler tested was an older style retrofitted with experimental low-emission burners. More testing is expected before any definitive conclusions are made concerning the effect on corrosion of low-NO_x operation with high sulfur coals.

To allow for the possibility of aggravated corrosion during low-NO_x operation with high sulfur coal, the EPA specified a higher NO_x emission limit of 0.6 lb $NO_x/10^6$ Btu heat input for high sulfur coal. Similarly, since low sulfur subbituminous coal was expected to have a smaller effect on corrosion, during low NO_x operation, the EPA set a lower emission limit of 0.5 lb $NO_x/10^6$ Btu heat input for low sulfur subbituminous coal.

Several studies also indicated that NO_x emissions during the combustion of coal-derived fuels, such as liquid solvent-refined coal and low Btu synthetic gas, might be higher than those from petroleum oil or natural gas, because these coal-derived fuels have higher bound-nitrogen-approaching levels in coal rather than in the naturally occurring oil and gas. To account for this possibility, the EPA set the emission limit for liquid and gaseous fuels derived from coal at 0.5 lb $NO_x/10^6$ Btu heat input rather than at the 0.3 or 0.2 lb $NO_x/10^6$ Btu heat input value for the naturally occurring liquid and gaseous fuels. Corrosion and other boiler problems are expected to occur during low-NO_x operation with these fuels because of their low sulfur and ash contents.

Based on the foregoing considerations, it is evident that the EPA set the June 1979 NSPS NO_x emission limits at levels with which industry could realistically comply. Implementation of the means of meeting the limits in new facilities burning high sulfur bituminous coal, such as considered in this study, would be provided by the boiler manufacturers and would not require any NO_x control components external to the boiler.

A5.2.2 NO_x Formation and Control Technical Considerations

To provide an understanding of the options available for meeting the 1979 NSPS NO_x standards, and those available for meeting possible future ones, the following discusses the various considerations involved in NO_x formation and control.

The formation of NO_x is dependent upon operating conditions and the amount of nitrogen present in the combustion process. Nitrogen is found in both the fuel and the air used to support the combustion. Air, for example is comprised of 76.85 percent (by wt) nitrogen. This means that for every 1 lb of oxygen required to support combustion, 3.32 lb of nitrogen are present. Although not directly involved in the combustion process, this nitrogen is a potential source of NO_x formation.

To assure the complete combustion of coal, it is necessary to introduce the fuel into the furnace in the smallest practical size. This is achieved by pulverization which breaks the coal into a powdery consistency. In this form it is conveyed by the primary, or motive, air into the furnace. The combustion process which then takes place in the furnace can be divided into three stages

1. Devolatilization during which matter is driven from the coal particles in the form of gas or tar as the particles are heated. During this stage some of the fuel-bound nitrogen is released, while the remainder is retained in the char.

2. Gaseous combustion during which the gaseous fuel produced in the devolatilization stage is burned with oxygen in the combustion air. This occurs providing ignition conditions are met.

3. Solid burn out during which the char, remaining after devolatilization, and the solids, resulting from the gaseous combustion, are oxidized.

The fuel-bound nitrogen, oxidized during the combustion of the gaseous and solid components, forms nitric oxide (NO). This NO is further oxidized to form nitrogen dioxide (NO_2). At high combustion temperatures, the normally inert nitrogen present in the combustion air also reacts with the oxygen in the air to form NO. This is generally referred to as thermal NO_x, and its formation becomes particularly effective at above 2800° F (1811° K).

NO_x control in a coal-fired steam generator can be broken into three methods: combustion temperature control, flue gas treatment and operating practices.

As already noted, NO_x formation is enhanced significantly when combustion temperatures are higher than 2800° F (1811° K). The intent of combustion temperature control, therefore, is to maintain temperatures below 2800° F (1811° K) to minimize NO_x formation without adversely affecting the heat release rates in the furnace. The techniques most commonly applied to coal-fired steam generators to achieve this are: using two-stage combustion, removing one or more burners from service, increasing the combustion zone and installing specially designed low NO_x burners. For two-stage combustion, combustion air is delivered at two points. The first is at the burner, where the combustion temperature is at its peak. The air flow is controlled to provide 90 to 95 percent of the theoretical stoichiometric requirements resulting in a fuel-rich mixture. Fuel-bound nitrogen is released here as molecular nitrogen (N_2), and partial combustion takes place. The second delivery point is downstream of the burner where the temperature is lower and combustion is completed. The net result is the reduction of NO_x emissions by 30 to 50 percent (Ref. A15). The two-stage combustion technique has been well tested in the field and has indicated that there can be essentially no boiler performance degradation associated with its use.

Similar NO_x reduction can be achieved by removing burners from service. This is basically another form of two stage combustion which is accomplished by shutting down the pulverizer supply to one or more of the upper level burners. Effectively, this technique transfers additional loading to the burners left in service if the heat input is to remain the same. In this technique, the lower burners partially combust a fuel-rich mixture and the upper level burners provide the second stage combustion air to complete the process. The attractiveness of this technique is that it can be readily retrofitted to an existing boiler with minimal hardware changes. However, in many cases the lower burners cannot accommodate the extra fuel flow, which results in the requirement that the boiler be derated perhaps 10 to 25 percent.

Staged combustion effectively increases the combustion zone, as the second stage of combustion takes place in an extended region of the furnace increasing the flame length. This effect can also be achieved by spreading the burners vertically, enlarging the furnace, using tangentially or corner-fired designs, or using an over-fire air system. The over-fire air system provides for the introduction of up to 20 percent of the combustion air above the lowest fuel admission nozzles. Since extending the flame length extends the combustion zone to higher elevations, it may result in excessive steam and tube temperatures in a retrofit situation requiring additional superheat attemperation. The over-fire system has been demonstrated to be capable of reducing NO_x 30 to 50 percent in coal-fired boilers (Ref. A15).

The development of low NO_x burners is about ten years old and may be considered to be entering an advanced stage of development. The design of the low-NO_x burner provides a full rich atmosphere for the initial combustion stage and reduces the flame turbulence to control the air/fuel mixing ratio. The EPA has sponsored testing of one type of low-NO_x burner (Ref. A16), which is reported to have maintained NO_x emissions below 0.2 $lb/10^6$ Btu in a coal-fired facility. Testing was with an experimental single burner

system operating at 105 x 10^6 Btu/hr. One manufacturer claims an effective 47 percent reduction in NO_x emissions with the use of its low-NO_x burner design (Ref. A17).

The designs of these two low-NO_x burners vary in detail, but their overall concepts are similar. A central fuel-rich zone is established and secondary air is injected through an annulus around the central zone. Tertiary air is injected from the furnace wall. Swirl is provided at primary and secondary feed points to control the length and width of the flame. In experimental tests (Ref. A18), it was found that NO_x emissions for three burner sizes (12, 50 and 100 x 10^6 Btu/hr) were below the equivalent of 0.2 lb/10^6 Btu heat input. This is about 67 percent less than the 1979 NSPS limit of 0.6 lb/10^6 Btu heat input, for coal fired plants.

With the development of the low-NO_x burner, most new utility boilers are expected to be able to meet current NO_x emission standards. However, future more restrictive standards may require additional modifications or <u>flue gas treatment</u> external to the boiler, which is discussed next. It is noted that the stringent NO_x emission limit in Japan, less than half of that permitted in the USA, has resulted in that country being the most advanced in flue gas treatment technology (Ref. A19). Japan has therefore provided a primary source of information concerning flue gas treatment.

Two types of flue gas (or post combustion) treatment are currently being developed: selective catalytic reduction (SCR) and noncatalytic reduction. Of these two, the selective catalytic reduction process has achieved the greatest success to date. This process has been developed in different forms each of which is based on the affinity of ammonia (NH_3) to combine with NO_x in the flue gas. The basic reactions that occur are

$$4NH_3 + 4NO + O_2 \xrightarrow{\text{catalyst}} 4N_2 + 6H_2O$$

$$4NH_3 + 2NO_2 + O_2 \xrightarrow{\text{catalyst}} 3N_2 + 6H_2O.$$

As approximately 95 percent of the NO_x in the flue gas is in the form of NO, the first of these reactions predominates. The SCR

process requires a reactor, a catalyst and an ammonia storage and injection system. The additional pressure drop across the reactor creates the need for additional boiler fan capacity with accompanying system energy losses. The optimum temperature for the NH_3/NO_x reaction with no catalyst is about 1850° F (1283° K). The catalyst, though, reduces this temperature to 600° to 800° F (589° to 700° K), and permits the reactor to be placed between the boiler economizer and preheater. The catalyst used in the process is proprietary with metal-based oxides, titanium oxide and vanadium pentoxide being the most preferred. Although this process has been demonstrated to remove up to 90 percent of the flue gas NO_x, it is not without problems. The most difficult of these include poisoning of the catalyst by flue gas constituents (particularly SO_x), plugging of the reactor with flue gas particles, and formation of ammonium sulfate and bisulfate, which are highly corrosive, and their deposition on the air preheater. To overcome these problems, work is in progress to determine optimum reactor designs (fixed and moving bed, parallel flow), develop poison resistant catalysts and develop methods to avoid the formation of the corrosive products.

Similar to the selective catalytic reduction methods of NO_x control, the non-catalytic reduction methods are also based on the reaction between ammonia and NO_x to produce nitrogen and water (Refs. A20 and A21). The reaction is enhanced by the presence of oxygen within a critical temperature range. The basic reactions that occur are

$$4NO + 4NH_3 + O_2 \rightleftarrows 4N_2 + 6H_2O$$

$$4NH_3 + 5O_2 \rightleftarrows 4NO + 6H_2O.$$

The former reaction predominates at temperatures around 1750° F (1227° K), whereas the latter one dominates around 2000° F (1366° K). Below 1600° F (1144° K), the rates of both reactions drop sharply, and the NH_3 flows through unreacted. The point of NH_3 injection, therefore, has to be carefully selected, and provisions must be made

to account for temperature changes due to fuel fluctuations, load changes, ash deposition, etc. Multiple or mobile injection points and the injection of hydrogen, which has been found to lower the optimum temperature range, have been applied with some success.

The most notable non-catalytic reduction system in commercial use is based on the Exxon $DeNO_x$ Process (Ref. A20); one system is installed in Japan. This system is claimed to have achieved a NO_x reduction of 70 percent. There have also been five test systems installed in the U.S.A. on 130 to 800 MWe plants firing bituminous, subbituminous and lignite coals (Ref. A22). These test systems have indicated that with the Thermal $DeNO_x$ Process alone, the June 1979 NSPS for NO_x could be complied with on all units. In combination with combustion modifications, all but the lignite fired plant achieved emissions in the 0.3 to 0.4 lbs/10^6 Btu heat input range, which represented NO_x reductions of 62 to 76 percent.

As noted earlier, low excess air can also be used to provide NO_x control. This is an example of control by means of modified operating practices. The formation of NO_x during the combustion process is dependent upon the oxygen available. In normal practice, the combustion air is maintained above the stoichiometric requirement by about 15 to 20 percent (i.e., above the stoichiometric oxygen requirement by about 3 to 4 percent). Operation with less air tends to reduce the formation of NO_x. In addition, it produces other beneficial effects such as a reduced heat loss up the stack and fan horsepower. In older installations, there was a practical limit below which the excess air could not be reduced. Dropping below this limit caused incomplete combustion and degraded combustion efficiency. It was found that the minimum excess air limit varied for each installation and could be determined in the field by analyzing flue gas CO content as the excess air was reduced. As the low excess air limit was in the neighborhood of 1.5 percent, NO_x control by this effect was small compared to the methods previously discussed.

In the light of the foregoing, flue gas treatment holds promise for meeting future more restrictive NO_x standards. However, it

introduces added complexity into plant operation and maintenance and affects plant reliability. Before it gains general acceptance by the utility industry, therefore, additional testing and evaluation will be required.

Appendix B

Method of Cost Escalation

Escalation of costs from the mid-1975 values presented in the ECAS report (Ref. A1) to the mid-1978 values presented in this report was carried out in a straightforward manner by applying appropriate escalation factors derived from the Handy-Whitman Index of Public Utility Construction Costs (Ref. A23) to each Federal Energy Regulatory Commission (FERC) Account. Table XXV lists the mid-1975 and mid-1978 Handy-Whitman indices for each account and the associated escalation factor computed as the ratio of the mid-1978 value to the mid-1975 one.

TABLE XXV. - ACCOUNT FACTORS USED TO ESCALATE THE ECAS REFERENCE POWER PLANT COSTS FROM MID-1975 TO MID-1978 FOR A PLANT LOCATED IN "MIDDLETOWN" IN THE NORTH CENTRAL REGION OF THE U.S.A.

FERC Account Number	Account Title	Handy-Whitman Index (Ref. A23)		Escalation Factor
		Mid-1975	Mid-1978	
310.	Land and Land Rights	— Not included in study —		
311.	Structures and Improvements (average)	384	445	1.16
312.	Boiler Plant	398	495	1.24
314.	Steam Turbine-Generator and Auxiliaries	272	346	1.27
315.	Accessory Electric Equipment	296	363	1.23
316.	Miscellaneous Power Plant Equipment	345	431	1.25
350.	Transmission Plant	372	426	1.15

The Handy-Whitman indices are developed by Whitman, Requardt and Associates of Baltimore, Maryland, and include, among other things, the prices of basic materials such as cement, sand, gravel,

pipe, wire, etc., obtained from publications such as the "Engineering News Record (Ref. A24);" labor rates, obtained from sources such as the U.S. Department of Labor, contractors' associations and labor unions; and equipment costs obtained from nationally recognized manufacturers.

In computing the indices, the basic proportions of materials, labor and equipment included are based on value analyses, design assignments and data fur-'shed to Whitman, Requardt and Associates by utility and industr... sources participating in the index development. The data are reportedly reviewed on a regular basis and weightings and components are revised periodically to assure that the published figures reflect current contractor practices.

To account for differing cost trends throughout the 48 contiguous states, the Handy-Whitman indices are calculated for six geographic regions having generally similar characteristics within their boundaries. The six regions are the North Atlantic, South Atlantic, North Central, South Central, Plateau (southwest) and pacific. As noted in section 3.0, the characteristic of the North Central region were adopted for the purposes of this study.

Appendix C

Reference Tables

This appendix contains copies of the tables on which the cost estimates for the ECAS and modified references plants are based. These tables were first published in the "Energy Conversion Alternatives Study (ECAS) Conceptual Design and Implementation Assessment of a Utility Steam Plant With Conventional Furnace and Wet Lime Stack Gas Scrubbers (Ref. A1)." Table XXVI lists the balance of plant equipment characteristics for the 250° F (394° K) stack gas reheat temperature case, and table XXVII lists the corresponding installation and balance of plant materials costs. Similarly, table XXVIII lists the balance of plant equipment characteristics for the 175° F (353° K) stack gas reheat temperature case, and table XXIX lists the corresponding installation and balance of plant materials costs.

Also included in this appendix is the breakdown of ECAS report (Ref. A1), table 16, Items 5.1, 5.2 and 5.3 into separate FERC Account 311. and 312. costs. This breakdown, presented in table XXX, is based on percentages of the combined cost of the three items estimated from a previous Burns and Roe study of a similar coal-fired plant.

TABLE XXVI. - ECAS REPORT TABLE 15
BALANCE OF PLANT EQUIPMENT LIST
CONVENTIONAL STEAM PLANT WITH WET LIME SCRUBBERS
250° F EXHAUST GAS TEMPERATURE
(REF. A1)

Eqpt. No.	Service	Description
	1.0 Coal & Limestone Handling Systems	
C-1	Coal Conveyor Belt	60 in wide, 340 ft long, 3000 tph
C-2	" " "	" " " 760 ft " " "
C-3	" " "	" " " 190 ft " " "
C-4	" " "	42 in " 980 ft " 500 tph
C-5	" " "	" " " 540 ft " " "
C-6	" " "	" " " 170 ft " " "
C-7	" " "	" " " 110 ft " " "
C-8	" " " (2 req'd.)	30 in " 160 ft " 300 tph
C-9	Limestone Conveyor Belt	60 in " 500 ft " 3000 tph
C-10	" " "	24 in " 630 ft " 65 tph
C-11	" " "	" " " 420 ft " " "
C-12	Limestone Bucket Conveyor	" " " 120 ft " 100 tph
C-13	Traveling Grate-Kiln System (Package)	650 ton/day nominal lime production (880 ton/day design capacity), 12 ft wide x 48 ft long traveling grate, 13 ft I.D. x 180 ft long rotary kiln with Niems-type cooler. Includes coal grinding/firing equipment, control panel/instrumentation, all refractories and drives, induced draft fan, baghouse dust collector and ducting.
C-14	Coal Conveyor Belt	18 in wide, 60 ft long, 20 tph
C-15	Lime Bucket Conveyor (2 req'd.)	24 in wide, 140 ft long, 40 tph
C-16	Fly Ash Silos (2 req'd.)	Total Volume 833,184 ft , 80 ft dia x 85 ft high
	2.0 Electrical Systems	
E-1	Main Transformers (2 req'd.)	468 MVA, FOA, 65 C, 24/500 kV
E-2	Unit Auxiliary Transformers (2 req'd.)	40/54/67 MVA, 65 C, OA/FA/FOA, 24/13.8 kV, 30, 60Hz

(sheet 1 of 3)

TABLE XXVI. - Continued

Eqpt. No.	Service	Description
E-3	Emergency Diesel Generator	1000 kW, 30, 60 Hz, 480 V, 0.8 PF
E-4	Start-up Transformer	28/37.5/47 MVA, OA/FA/FOA, 500/13.8 kV, FOA, 65 C, 30, 60 Hz
E-5	Miscellaneous 480V LCC Transformers (14 req'd.)	1689 kVA, OA, 65 C, 13.8 kV/489V/277V, 30, 60 Hz
E-6	Boiler Auxiliary Transformers (2 req'd.)	5500 kVA, OA, 65 C, 13.8/4.16kV, 30, 60 Hz
E-7	LCC Transformers (2 req'd.)	7000 kVA, OA, 65 C, 13.8/4.16 kV, 30, 60 Hz
E-8	Scrubber Transformers (2 req'd.)	5,000 kVA, OA, 65 C, 13.8/4.16 kV, 30, 60 Hz

3.0 Main Fluid Systems

Eqpt. No.	Service	Description
F-1	Main Condenser	3.31 x 10 ft of Heat Transfer Area Std. material.
F-2	Piping:	
	Circulating Water	I. D. = 114 in
	Main Steam	I. D. = 15.3 in, tm = 3.97 in
	Boiler Feed Water	I. D. = 26.53 in, tm = 0.675 in
	Cold Reheat	I. D. = 32.54 in, tm = 1.57 in
	Hot Reheat	I. D. = 18.1 in, tm = 2.25 in

Eqpt. No.	Feedwater Heaters:	Shell Press/Temp. psia/ F	Tube Press/Temp. psia/ F	Flow (100%) lb/hr	Heat Transfer Area ft
F-3	LP #1	5/163	210/158	4.05 x 10	14,330
	LP #2	11/195	210/190	4.05 x 10	13,550
	LP #3	20/228	210/223	4.05 x 10	13,720
	LP #4	67/300	210/295	4.05 x 10	18,770
	IP	296/416	1040/415	6.22 x 10	45,660
	H.P.	745/510	5,700/519	6.22 x 10	49,700
	DFT	6.22x10 lb/hr, @ 353 F			

Eqpt. No.	Service	Description
F-4	Main Condensate Pumps and Motors (2 req'd.)	Vertical Centerline, 4250 gpm, 600 hp motor, 410 ft TDH
F-5	Feedwater Booster Pumps & Motors (2 req'd.)	7,300 gpm, 3850 hp, 1510 ft TDH

(sheet 2 of 3)

TABLE XXVI. - Concluded

Eqpt. No.	Service	Description	
F-6	Main Boiler Feed Pumps & Turbine Drivers (3 req'd.)	4900 gpm, 12,600 hp, 8,300 ft TDH	
F-7	Main Circulating Pumps and Motors (3 req'd.)	82,000 gpm, 2250 hp, 75 ft TDH	
F-8	Cooling Towers (20 Cells)	246,000 gpm	
F-9	Forced Draft Fans (2 req'd.)	Operating	971,000 cfm @ 80°F, S.P. = 19 in wg
		Test Block	1,165,000 cfm @ 105°F, S.P. = 24.7 in wg
		Motor	6500 hp
F-10	Primary Air Fans (2 req'd.)	Operating	161,750 cfm @ 96 F, S.P. inlet 19 in wg, S.P. outlet = 42 in wg
		Test Block	194,000 cfm @ 121 F, S.P. inlet 19 in wg, S.P. outlet = 54.6 in wg
		Motor	2250 hp
F-11	Electrostatic Precipitators (4 req'd.)	Each 54 ft high x 92 ft wide x 44 ft long, 1,262,000 lb, 1296 kVA, 99% particulate removal efficiency, 695,000 acfm @ 300°F.	
F-12	Scrubber - Turbulent Contact Absorber (6 req'd.)	Each 60 ft high x 40 ft wide x 18 ft long, 316L-S.S., neoprene lined, 3 stages, 450,000 acfm @ 312°F & 13.9 psia.	
F-13	Air Heater (6 req'd.)	Each 4.5 ft high x 21.5 ft wide x 37.5 ft long .	
F-14	Induced Draft Fans (4 req'd.)	Operating	660,000 cfm @ 300°F, Total S.P. = 23 in wg
		Test Block	800,000 cfm @ 325°F, Total S.P. = 30 in wg
		Motor	5,000 hp
F-15	Forced Draft Fans for Reheater Air (6 req'd.)	Operating	545,000 cfm @ 80°F, Total S.P. = 3.5 in wg
		Test Block	654,000 cfm @105°F, Total S.P. = 4.55 in wg
		Motor	650 hp
F-16	Exhaust Stack	40 ft I.D., 500 ft high	

(sheet 3 of 3)

TABLE XXVII. - ECAS REPORT TABLE 16
BALANCE OF PLANT ESTIMATE DETAIL FOR CONVENTIONAL STEAM CYCLE - WET GAS SCRUBBER - 250° F STACK
(REF. A1)

		Direct Manual Field Labor MH 1000's	Balance of Plant Material $ 1000's
1.0	STEAM GENERATOR (3)		
1.1	Steam Generator Erection		
-	Erect only (supply by others): includes heat transfer surface and pressure parts; buckstays, braces and hangers; fuel-burning equipment; accessories; soot and ash equipment; control systems; brickwork, refractory and insulation	544	
-	Supply and erect: includes support steel and access steel for above; miscellaneous materials and labor operations	296	6,800
1.2	Steam Generator Auxiliaries		
-	Erect only (supply by others): includes P.A. fans; air preheater; flues and ducts to precipitators; insulation for flues and ducts; pulverizers, feeders and hoppers	185	
-	Supply and erect: includes F.D. Fans (2 @ $390,000 ea*); I.D. fans (4 @ $220,000 ea.*)	12	1,680
1.3	Electrostatic Precipitators		
-	Erect only (supply by others): includes electrostatic precipitators	99	
-	Supply and erect: includes support steel for precipitators	4	220
		1,140	8,700
2.0	TURBINE GENERATOR (3)		
-	Install only (supply by others): includes 835 MWe steam turbine; generator; exciter; auxiliary equipment; integral steam and auxiliary piping; insulation; miscellaneous labor operations	120	100

*based on suppliers' verbal budgetary quotations

(sheet 1 of 7)

TABLE XXVII. - Continued

	Direct Manual Field Labor MH 1000's	Balance of Plant Material $ 1000's
3.0 PROCESS MECHANICAL EQUIPMENT		
3.1 Boiler Feedwater Pumps (3)		
includes turbine-driven main feedwater pumps and drivers (3@ $940,000 ea.*); feedwater booster pumps and motors (2 @ $125,000 ea.*)	10	3,220
3.2 Main Circ. Water Pumps (3)		
includes main circ. water pumps and motors (3 @ $220,000 ea*)	3	700
3.3 Other Pumps (3)		
includes condensate pumps and motors (2@ $85,000 ea.*); and other pumps and drivers not listed elsewhere	5	650
3.4 Main Condenser* (3)		
includes shells; tubes; air ejectors	16	2,120
3.5 Heaters, Exchangers, Tanks and Vessels (3)		
includes l.p. feedwater heaters (4): i.p. feed water heater; h.p. feedwater heater; deaerating heater and storage tank; miscellaneous heaters and exchangers; tanks and vessels	9	3,060
3.6 Stack and Accessories (3)		
includes concrete stack and liner*; lights and marker painting; hoists and platforms; stack foundation	113	1,570
3.7 Turbine Hall Crane (1)		
includes crane and accessories	3	410
3.8 Coal Handling (2)		
includes railcar dumping equipment; dust collectors; primary and secondary crushing equipment; belt scale; sampling station; magnetic cleaners; mobile equipment; conveyors to pile; reclaiming feeders; conveyors to coal silos; coal silos	61	5,640

*based on suppliers' verbal budgetary quotations

(sheet 2 of 7)

TABLE XXVII. - Continued

	Direct Manual Field Labor MH 1000's	Balance of Plant Material $ 1000's
3.9 Limestone Handling (3)		
includes magnetic cleaners; conveyor to lime stone pile; reclaiming feeders; belt scale; conveyors to calciner	22	1,250
3.10 Ash Handling (2)		
includes bottom ash system; fly ash handling system for precipitators and air preheater; ash conveyors; ash storage silos (2) with feeders, unloaders and foundations; railcar loading equipment	61	3,580
3.11 Cooling Towers* (3)		
includes mechanical draft towers with fans and motors	52	2,230
3.12 Other Mechanical Equipment (3)		
includes water treatment and chemical injection; air compressors and auxiliaries; fuel oil ignition and warm-up; screenwell, miscellaneous plant equipment; equipment insulation	30	1,660
3.13 Scrubber Ductwork (3)	207	3,270
- includes flue gas duct outboard of electrostatic precipitators; duct lining; duct insulation; dampers and expansion joints		
3.14 Scrubber Flue Gas Equipment (3)	27	3,090
- includes F.D. fans for flue gas reheat (6 @ $200,000 ea.*); air heaters for flue gas reheat (6 @ $280,000 ea*)		
3.15 Wet Lime SO_2 Scrubbers (3)	86	6,930
- includes complete SO_2 scrubber vessels with presaturator and mist eliminator systems (6 @ $1,000,000 ea*)		

*based on suppliers' verbal budgetary quotations

(sheet 3 of 7)

TABLE XXVII. - Continued

		Direct Manual Field Labor MH 1000's	Balance of Plant Material $ 1000's
	3.16 Scrubber Lime System (3)	66	3,660
	- includes limestone calciner with travelling grate kiln ($2,700,000*); Kiln stack; coal conveyor, bucket elevator and storage bin for kiln; lime conveyor, bucket elevator and storage silos; lime slaker ($120,000*)		
	3.17 Scrubber System Pumps (3)	10	1,080
	- includes slurry recycle (18 @ $40,000 ea*); mist eliminator wash (3 @ $25,000 ea.*); slurry storage and transfer (4 @ $4,000 ea*); slurry feed (3 @ $5,000 ea*); pond feed tank (3 @ $10,000 ea*); pond feed booster (2 @ $15,000 ea*); pond water recycle and booster (4 @ $12,500 ea*);		
	3.18 Scrubber System Tanks (3)	4	2,180
	- includes tanks and agitators for absorber effluent hold, pond feed, entrainment separator surge, slurry surge, slurry storage, slurry transfer		
		785	46,300
4.0	ELECTRICAL (5)		
	4.1 Main Transformers*	4	2,020
	4.2 Other Transformers* and Main Bus	17	1,280
	- includes startup transformer; station service transformers including those for scrubber system; generator main bus		
	4.3 Switchgear and Control Centers	42	3,400
	- includes switchgear and load centers; motor control centers; local control stations; distribution panels, relay and meter boards		
	4.4 Other Electrical Equipment	363	2,010
	- includes communications; grounding; cathodic and freeze protection; lighting; pre-operational testing		

*based on suppliers' verbal budgetary quotations

(sheet 4 of 7)

TABLE XXVII. - Continued

			Direct Manual Field Labor MH 1000's	Balance of Plant Material $ 1000's
	4.5	Auxiliary Diesel Generator	2	110
	-	includes diesel generator, batteries and associated d. c. equipment		
	4.6	Conduit, Cable Trays, Wire and Cable	632	4,080
			1,060	12,900
5.0	CIVIL AND STRUCTURAL			
	5.1	Concrete Substructures and Foundations (1)	340	2,800
	-	includes turbine and boiler building sub-structure; coal, limestone and ash handling foundations, pits and tunnels; miscellaneous equipment foundations; auxiliary buildings substructures; miscellaneous concrete		
	5.2	Superstructures (1)	275	7,960
	-	includes turbine building; auxiliary yard buildings; boiler enclosure		
	5.3	Earthwork (1)	130	300
	-	includes building excavations; coal, limestone and ash handling excavations; circ. water system excavations; miscellaneous foundation excavations; dewatering and piling		
	5.4	Cooling Tower Basin and Circ. Water System (3)	90	1,380
	-	includes circ. water pump pads, riser and concrete envelope for pipe; cooling tower basin; circ. water pipe; cooling tower miscellaneous steel and fire protection		
	5.5	SO2 Scrubber Civil and Structural (1)	180	3,660
	-	includes foundations, earthwork and structures particular to scrubber equipment		
			1,015	16,100

(sheet 5 of 7)

TABLE XXVII. Continued

		Direct Manual Field Labor MH 1000's	Balance of Plant Material $ 1000's
6.0	PROCESS PIPING AND INSTRUMENTATION		
6.1	Steam and Feedwater Piping (3)	81	3,850
-	includes main steam; extraction steam; hot reheat; cold reheat; feedwater and condensate large piping, valves and fittings		
6.2	SO2 Scrubber System Large Piping (3)	53	2,630
-	includes make-up water; resaturation slurry water; mist eliminator wash; absorber slurry effluent tank overflow; pond feed; pond recycle water; lime slurry piping; recycle slurry piping; air heater steam supply; air heater condensate return		
6.3	Other Large Piping (3)	231	4,050
-	includes auxiliary steam; process water; auxiliary systems		
6.4	Small Piping (3)	152	1,350
-	includes all piping, valves and fittings of 2 inch diameter and less		
6.5	Hangers and Misc. Labor Operations (3)	420	1,460
-	includes all hangers and supports; material handling; scaffolding; misc. labor operations		
6.6	Pipe Insulation (3)	63	660
6.7	Instrumentation and Controls (5)	220	4,900
		1,220	18,900
7.0	YARDWORK AND MISCELLANEOUS (1)		
7.1	Site Preparation and Improvements	87	10
-	includes soil testing; clearing and grubbing; rough grading; finish grading; landscaping		
7.2	Site Utilities	5	50
-	includes storm and sanitary sewers; non-process service water		

(sheet 6 of 7)

TABLE XXVII. - Concluded

		Direct Manual Field Labor MH 1000's	Balance of Plant Material $ 1000's
7.3	Roads and Railroads	27	740
-	includes railroad spur; roads, walks and parking areas		
7.4	Yard Fire Protection, Fences and Gates	52	600
7.5	Water Treatment Ponds	88	20
-	includes earthwork; pond lining; offsite pipeline		
7.6	Lab, Machine Shop and Office Equipment	1	280
		260	1,700

TABLE XXVIII. - ECAS REPORT TABLE 27
EQUIPMENT LIST FOR CONVENTIONAL STEAM CYCLE -
WET SCRUBBERS, 175° F STACK
(REF. A1)

EQPT. NO.	SERVICE	DESCRIPTION
	1. Coal, & Limestone Handling Systems	
C-1	Coal Conveyor Belt	60 in wide, 340 ft long, 3000 tph
C-2	" " "	60 in " 760 ft " 3000 "
C-3	" " "	60 in " 190 ft " 3000 "
C-4	" " "	42 in " 980 ft " 500 "
C-5	" " "	42 in " 540 ft " 500 "
C-6	" " "	42 in " 170 ft " 500 "
C-7	" " "	42 in " 110 ft " 500 "
C-8	" " " (2)	30 in " 160 ft " 300 "
C-9	Limestone Conveyor Belt	60 in " 500 ft " 3000 "
C-10	" " "	24 in " 630 ft " 65 "
C-11	" " "	24 in " 420 ft " 65 "
C-12	Limestone Bucket Conveyor	24 in " 120 ft " 100 "
C-13	Traveling Grate Kiln System (Package)	650 ton/day nominal lime production (880 ton/day design capacity), 12 ft wide x 48 ft long traveling grate, 13 ft I.D. x 180 ft long rotary kiln with Niems type cooler. Includes coal grinding/firing equipment, control panel/instrumentation, all refractories and drives, induced draft fan, baghouse dust collector and ducting.
C-14	Coal Conveyor Belt	18 in wide 60 ft long 20 tph
C-15	Lime Bucket Conveyor (2)	24 in " 140 ft " 40 "
C-16	Fly Ash Silos (2)	Total Volume 833,184 ft^3, 80 ft dia x 85 ft high

TABLE XXVIII. - Continued

EQPT. No.	SERVICE	DESCRIPTIONS
	2. Electrical Systems	
E-1,2	Main Transformers (2)	468 MVA FOA 65°C, 24/500 kV
E-3,4	Unit Aux. Transformers (2)	40/54/67 MVA 65°C, OA/FA/FOA,24/13.8 kV, 3Ø, 60Hz
E-5	Emergency Diesel Gen.	1000 kW 3Ø, 60 Hz, 480 V, 0.8 PF
E-6	Start-up Transformer	28/37.5/47 MVA,OA/FA/FOA,500/13.8 kV FOA 65°C 3Ø, 60 Hz
E-7 thru 20	Miscellaneous 480V LCC Transformers(14)	1689 kVA, OA, 65°C, 13.8 kV/ 480V/277V 3Ø, 60 Hz
E-21 & 22	BLR. Aux. Transformers (2)	5500 kVA, OA, 65°C, 13.8/4.16kV,3Ø, 60 Hz
E-23 & 24	LCC Transformers (2)	7000 kVA, OA, 65°C, 13.8/4.16 kV, 3Ø, 60 Hz
E-25 &26	Scrubber Transformers (2)	5,000 kVA, OA, 65°C, 13.8/4.16 KV, 3Ø, 60 Hz
	3. Main Fluid Systems	
F-1	Main Condenser	3.97×10^5 ft^2 of Heat Transfer Area
F-2	Piping	
	Circ. Water	I. D. = 123 in

TABLE XXVIII. - Continued

EQPT No.	SERVICE	DESCRIPTION			
	Main Steam	I. D. = 15.3 in, tm = 3.97 in			
	B.F.W.	I. D. = 26.52 in, tm = 0.675 in			
	Cold R. H.	I. D. = 32.54 in, tm = 1.57 in			
	Hot R. H.	I. D. = 18.1 in, tm = 2.25 in			
F-3	Feedwater Heaters	Shell Press/Temp psia/°F	Tube Press/Temp psia/°F	Flow (100%) lb/hr	Heat Transfer Area ft^2
	LP #1	5/163	210/158	4.75×10^6	17,170
	LP #2	11/195	210/190	4.75×10^6	16,260
	LP #3	20/228	210/223	4.75×10^6	16,600
	LP #4	67/300	210/295	4.75×10^6	22,710
	IP	296/416	1040/416	6.22×10^6	45,660
	H.P.	745/510	5,700/519	6.22×10^6	49,700
	DFT	6.22×10^6 lb/hr , @ 353°F			
F-4	Main Cond. Pumps and motors (2)	Vert. Cent. 5100 gpm, 750 hp motor, 410 ft TDH			
F-5	F.W. Booster Pumps & Motors (2)	7,300 gpm, 3850 hp, 1510 ft TDH			
F-6	Main Boiler Feed Pumps & Turbine Drivers (3)	4900 gpm, 12,600 hp, 8,300 ft TDH			
F-7	Main Circ. Pumps and Motors (3)	95,000 gpm 2500 hp, 75 ft TDH			
F-8	Cooling Towers (23 Cells)	242,058 gpm.			
F-9	F.D.Fans (2)	Operating 971,000 cfm @ 80°F, S.P. = 19 in wg Test Block 1,165,000 cfm @105°F, S.P. = 24.7 in wg Motor 6500 hp			

(sheet 3 of 4)

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TABLE XXVIII. - Concluded

EQPT. No.	SERVICE	DESCRIPTION	
F-10	P.A. Fans (2)	Operating	161,750 cfm @ 96°F, S.P. inlet in wg S.P. outlet = 42 in wg
		Test Block	194,000 cfm @ 121°F, S.P. inlet 19 in wg S.P. outlet = 54.6 in wg
		Motor	2250 hp
F-11	Electrostatic Precipitators (4)	Each 54 ft high x 92 ft wide x 44 ft long, 1,262,000 lb, 1296 kVA, 99% particulate removal efficiency, 695,000 acfm @ 300°F.	
F-12	Scrubber - Turbulent Contact Absorber (6)	Each 60 ft high x 40 ft wide x 18 ft long, 316L-S.S, neoprene lined, 3 stages, 450,000 acfm @312°F & 13.9 psia.	
F-13	Air Heaters (6)	Each 2.5 ft high x 18.2 ft wide x 10.7 ft long.	
F-14	I.D. Fans (4)	Operating	660,000 cfm @300°F, Total S.P.=23 in wg
		Test Block	800,000 cfm @325°F, Total S.P.=30 in wg
		Motor	5,000hp
F-15	F.D. Fans for Reheater Air (6)	Operating	123,000 cfm @ 80°F, Total S.P.=3.5 in wg
		Test Block	147,000 cfm @105°F, Total S.P.=4.55 in wg
		Motor	150 hp
F-16	Exhaust Stack (1)	27 ft I.D., 500 ft high	

(sheet 4 of 4)

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TABLE XXVIII. - Concluded

EQPT. No.	SERVICE	DESCRIPTION
F-10	P.A. Fans (2)	Operating 161,750 cfm @ $96^{\circ}F$, S.P. inlet in wg S.P. outlet = 42 in wg Test Block 194,000 cfm @ $121^{\circ}F$, S.P. inlet 19 in wg S.P. outlet = 54.6 in wg Motor 2250 hp
F-11	Electrostatic Precipitators (4)	Each 54 ft high x 92 ft wide x 44 ft long, 1,262,000 lb, 1296 kVA, 99% particulate removal efficiency, 695,000 acfm @ $300^{\circ}F$.
F-12	Scrubber - Turbulent Contact Absorber (6)	Each 60 ft high x 40 ft wide x 18 ft long, 316L-S.S, neoprene lined, 3 stages, 450,000 acfm @$312^{\circ}F$ & 13.9 psia.
F-13	Air Heaters (6)	Each 2.5 ft high x 18.2 ft wide x 10.7 ft long.
F-14	I.D. Fans (4)	Operating 660,000 cfm @$300^{\circ}F$, Total S.P.=23 in wg Test Block 800,000 cfm @$325^{\circ}F$, Total S.P.=30 in wg Motor 5,000hp
F-15	F.D. Fans for Reheater Air (6)	Operating 123,000 cfm @ $80^{\circ}F$, Total S.P.=3.5 in wg Test Block 147,000 cfm @$105^{\circ}F$, Total S.P.=4.55 in wg Motor 150 hp
F-16	Exhaust Stack (1)	27 ft I.D., 500 ft high

(sheet 4 of 4)

TABLE XXIX. - ECAS REPORT TABLE 28
BALANCE OF PLANT ESTIMATE DETAIL CONVENTIONAL STEAM CYCLE - WET LIME STACK GAS SCRUBBER, 175° F STACK GAS
(REF. A1)

	Direct Manual Field Labor MH 1000's	Balance of Plant Material $ 1000's
1.0 STEAM GENERATOR		
1.1 Steam Generator Erection (3)		
- Erect only (supply by others): includes heat transfer surface and pressure parts; buckstays, braces and hangers; fuel burning equipment; accessories; soot and ash equipment; control systems; brickwork; refractory and insulation	544	
- Supply and erect: includes support steel and access steel for above; miscellaneous materials and labor operations	296	6,800
1.2 Steam Generator Auxiliaries (3)		
- Erect only (supply by others): includes P.A. fans; air preheater; flues and ducts to precipitators; insulation for flues and ducts; pulverizers, feeders and hoppers	185	
- Supply and erect: includes F.D. Fans (2 @$390,000 ea*); I.D. fans (4 @$220,000 ea.*)	12	1,680
1.3 Electrostatic Precipitators (3)		
- Erect only (supply by others): includes electrostatic precipitators	99	
- Supply and erect: includes support steel for precipitators	4	220
	1,140	8,700
2.0 TURBINE GENERATORS (3)		
- Install only (supply by others): includes 835 MWe steam turbine; generator; exciter; auxiliary equipment; integral steam and auxiliary piping; insulation; miscellaneous labor operations	120	100

*based on suppliers' verbal budgetary quotations

(sheet 1 of 7)

TABLE XXIX. - Continued

		Direct Manual Field Labor MH 1000's	Balance of Plant Material $ 1000's
3.0	PROCESS MECHANICAL EQUIPMENT		
3.1	Boiler Feedwater Pumps (3)		
-	includes turbine-driven main feedwater pumps and drivers (3 @ $940,000 ea. *); feedwater booster pumps and motors (2 @$125,000 ea. *)	10	3,220
3.2	Main Circ. Water Pumps (3)		
-	includes main circ. water pumps and motors (3 @ $235,000 ea*)	3	750
3.3	Other Pumps (3)		
-	includes condensate pumps and motors (2 @ $95,000 ea. *); and other pumps and drivers not listed elsewhere	5	670
3.4	Main Condenser* (3)		
-	includes shells; tubes; air ejectors	17	2,440
3.5	Heaters, Exchangers, Tanks and Vessels (3)		
-	includes l.p. feedwater heaters (4): i.p. feed water heater; h.p. feedwater heater; deaerating heater and storage tank; miscellaneous heaters and exchangers; tanks and vessels	9	3,160
3.6	Stack and Accessories (3)		
-	includes concrete stack and liner*; lights and marker painting; hoists and platforms; stack foundation	86	1,240
3.7	Turbine Hall Crane (1)		
-	includes crane and accessories	3	410
3.8	Coal Handling (2)		
-	includes railcar dumping equipment; dust collectors; primary and secondary crushing equipment; belt scale; sampling station; magnetic cleaners; mobile equipment; conveyors to pile; reclaiming feeders; conveyors to coal silos; coal silos	61	5,640

*based on suppliers' verbal budgetary quotations

(sheet 2 of 7)

TABLE XXIX. - Continued

	Direct Manual Field Labor MH 1000's	Balance of Plant Material $ 1000's
3.9 Limestone Handling (3)		
- includes magnetic cleaners; conveyor to lime stone pile; reclaiming feeders; belt scale; conveyors to calciner	22	1,250
3.10 Ash Handling (2)		
- includes bottom ash system; fly ash handling system for precipitators and air preheater; ash conveyors; ash storage silos (2) with feeders, unloaders and foundations; railcar loading equipment	61	3,580
3.11 Cooling Towers* (3)		
- includes mechanical draft towers with fans and motors	60	2,580
3.12 Other Mechanical Equipment (3)		
- includes water treatment and chemical injection; air compressors and auxiliaries; fuel oil ignition and warm-up; screenwell; miscellaneous plant equipment; equipment insulation	30	1,660
3.13 Scrubber Ductwork (3)	120	1,950
- includes flue gas duct outboard of electrostatic precipitators; duct lining; duct insulation; dampers and expansion joints		
3.14 Scrubber Flue Gas Equipment (3)	7	900
- includes F.D. fans for flue gas reheat (6 @$85,000 ea.*); air heaters for flue gas reheat (6 @$50,000 ea.*)		
3.15 Wet Lime SO2 Scrubbers (3)	86	6,930
- includes complete SO2 scrubber vessels with pre-saturator and mist eliminator systems (6 @ $1,000,000 ea.*)		

*based on suppliers' verbal budgetary quotations

(sheet 3 of 7)

TABLE XXIX. - Continued

	Direct Manual Field Labor MH 1000's	Balance of Plant Material $ 1000's
3.16 Scrubber Lime System (3)	66	3,660
- includes limestone calciner with travelling grate kiln ($2,700,000*); Kiln stack; coal conveyor, bucket elevator and storage bin for kiln; lime conveyor, bucket elevator and storage silos; lime slaker ($120,000*).		
3.17 Scrubber System Pumps (3)	10	1,080
- includes slurry recycle (18 @$40,000 ea.*); mist eliminator wash (3 @$25,000 ea.*); slurry storage and transfer (4 @$4,000 ea.*); slurry feed (3 @$5,000 ea.*); pond feed tank (3 @$10,000 ea.*); pond feed booster (2 @ $15,000 ea.*); pond water recycle and booster (4 @$12,500 ea.*)		
3.18 Scrubber System Tanks (3)	4	2,180
- includes tanks and agitators for absorber effluent hold, pond feed, entrainment separator surge, slurry surge, slurry storage, slurry transfer		
	660	43,300
4.0 ELECTRICAL (5)		
4.1 Main Transformers*	4	2,020
4.2 Other Transformers* and Main Bus	17	1,280
- includes startup transformer; station service transformers including those for scrubber system; generator main bus		
4.3 Switchgear and Control Centers	42	3,400
- includes switchgear and load centers; motor control centers; local control stations; distribution panels, relay and meter boards		
4.4 Other Electrical Equipment	363	2,010
- includes communications; grounding; cathodic and freeze protection; lighting; pre-operational testing		

*based on suppliers' verbal budgetary quotations

(sheet 4 of 7)

TABLE XXIX. - Continued

		Direct Manual Field Labor MH 1000's	Balance of Plant Material $ 1000's
	4.5 Auxiliary Diesel Generator	2	110
	- includes diesel generator, batteries and associated d.c. equipment		
	4.6 Conduit, Cable Trays, Wire and Cable	632	4,080
		1,060	12,900
5.0	CIVIL AND STRUCTURAL		
	5.1 Concrete Substructures and Foundations (1)	340	2,800
	- includes turbine and boiler building substructures; coal, limestone and ash handling foundations, pits and tunnels; miscellaneous equipment foundations; auxiliary buildings substructures; miscellaneous concrete		
	5.2 Superstructures (1)	275	7,960
	- includes turbine building; auxiliary yard buildings; boiler enclosure		
	5.3 Earthwork (1)	130	300
	- includes building excavations; coal, limestone and ash handling excavations; circ. water system excavations; miscellaneous foundation excavations; dewatering and piling		
	5.4 Cooling Tower Basin and Circ. Water System (3)	105	1,680
	- includes circ. water pump pads, riser and concrete envelope for pipe; cooling tower basin; circ. water pipe; cooling tower miscellaneous steel and fire protection		
	5.5 SO2 Scrubber Civil and Structural (1)	180	3,660
	- includes foundations, earthwork and structures particular to scrubber equipment		
		1,030	16,400

(sheet 5 of 7)

TABLE XXIX. - Continued

		Direct Manual Field Labor MH 1000's	Balance of Plant Material $ 1000's
6.0	PROCESS PIPING AND INSTRUMENTATION		
6.1	Steam and Feedwater Piping (3)	81	3,850
-	includes main steam; extraction steam; hot reheat; cold reheat; feedwater and condensate large piping, valves and fittings		
6.2	SO2 Scrubber System Large Piping (3)	51	2,370
-	includes make-up water; resaturation slurry water; mist eliminator wash; absorber slurry effluent tank overflow; pond feed; pond recycle water; lime slurry piping; recycle slurry piping; air heater steam supply; air heater condensate return		
6.3	Other Large Piping (3)	231	4,050
-	includes auxiliary steam; process water; auxiliary systems		
6.4	Small Piping (3)	152	1,350
-	includes all piping, valves and fittings of 2 inch diameter and less		
6.5	Hangers and Misc. Labor Operations (3)	419	1,420
-	includes all hangers and supports; material handling; scaffolding; misc. labor operations		
6.6	Pipe Insulation (3)	62	640
6.7	Instrumentation and Controls (5)	219	4,820
		1,215	18,500
7.0	YARDWORK AND MISCELLANEOUS (1)		
7.1	Site Preparation and Improvements	87	10
-	includes soil testing; clearing and grubbing; rough grading; finish grading; landscaping		
7.2	Site Utilities	5	50
-	includes storm and sanitary sewers; non-process service water		

(sheet 6 of 7)

TABLE XXIX. - Concluded

		Direct Manual Field Labor MH 1000's	Balance of Plant Material $ 1000's
7.3	Roads and Railroads	27	740
-	includes railroad spur; roads, walks and parking areas		
7.4	Yard Fire Protection, Fences and Gates	52	600
7.5	Water Treatment Ponds	88	20
-	includes earthwork; pond lining; offsite pipeline		
7.6	Lab, Machine Shop and Office Equipment	1	280
		260	1,700

TABLE XXX. - BREAKDOWN OF ECAS REPORT (REF. A1) TABLE 16,
ITEMS 5.1, 5.2 AND 5.3 INTO SEPARATE
FERC ACCOUNT 311. AND 312. COSTS
(250° F Stack Gas Reheat Temperature (1))
(Mid-1975 Dollars)

Included in FERC Account Subdivision	Building/Structure/Excavation	Estimated Percent of Combined Cost of Items 5.1, 5.2, 5.3	ECAS Report Cost Breakdown (2)			
			Material Cost (10^3)	MH (10^3hr)	Installation Cost (10^3)	Indirect Cost (10^3)
	Combined Cost of Items 5.1, 5.2 & 5.3	100	11,060	745	8,754	7,882
311.3	Main (Turbine-Generator) Building	22	2,433	163.9	1,926	1,734
311.4	Steam Generator Building	54	5,972	402.3	4,727	4,256
311.6	Maintenance, Service, Warehouse and Office Building	7.5	830	55.9	657	591
311.7	Other Buildings (Including Makeup Intake Structure)	2	221	14.9	175	158
311.9	On-site Waste Treatment (Including Water Treatment) Building	0.5	55	3.7	14	39
312.1	Excavation for Coal and Limestone Handling and Circulating Water Systems	14	1,549	104.3	1,225	1,104

(1) Also applies to table 28 for the 175° F stack gas reheat temperature case.
(2) Costs are rounded to thousands of dollars.

Appendix D

Comparison of the ECAS and Modified Reference Plant Design Parameters

Table XXXI presents a comparison of the New Source Performance Standards in effect at the time of the ECAS study and those at the time of this study with the ECAS reference plant and modified reference plant design emission parameters, respectively.

Column 2 of the comparison lists the relevant limits applicable to each of the reference plants.

It is clear from the 1979 NSPS limits listed that each of the ECAS limits were significantly revised downward reflecting the greater demands on the utility industry to reduce emissions of pollutants to the environment. It is also clear that the particulate emissions limit received the most severe reduction by greater than a factor of 3, compared with the reduction of sulfur dioxide emissions by a factor of about 1.7, and nitrogen oxides by a factor of about 1.2. Of note is the absence of any reference to calciner emissions in the modified reference plant. This results from the deletion of on-site lime production from the modified plant for the reasons discussed in Appendix A, Technical Assessment A2.0. The calciner particulate emission limit listed for the ECAS plant is based on the Code of Federal Regulations, Subpart F - Standards of Performance for Portland Cement Plants (Ref. 3).

Column 3 of table II lists the design potential emissions from the ECAS and modified reference plants which would be released if no emission controls were applied. The word "design" should be recognized as indicating that these values are larger than mean (or average) operating values to provide a margin to account for the variability of the fuel characteristics as discussed in section 3.3 and section A1.0. The design values listed for the ECAS plant are based on the parameters as they appear in various places in the ECAS report (Ref. A1). The corresponding values for the modified plant are systematically calculated from the characteristics of the

TABLE XXXI. - COMPARISON OF THE ECAS REFERENCE STEAM POWER PLANT EMISSION PARAMETERS WITH THE ECAS EMISSION LIMIT REQUIREMENTS AND THE MODIFIED REFERENCE STEAM POWER PLANT EMISSION PARAMETERS WITH THE JUNE 1979 NSPS EMISSION LIMIT REQUIREMENTS

Emission/Origin	ECAS NSPS Emission Limit Required for Compliance	ECAS Reference Plant Reported Design Value			
		Potential Emission (1)	Reduced Emission	Percent Reduction (15)	
				Required	Provided
Particulates					
Boiler ($lb/10^6$ Btu heat input)	0.1	6.7 (2)	0.092 (4)	98.5	98.6
Calciner (lb/ton of limestone feed)	0.30 (5)	16.7 (3,5)	Unspecified (5)	Unspecified	
SO_2					
Boiler ($lb/10^6$ Btu heat input)	1.2	8.3	0.83 (6)	85.5	90.0
Calciner (lb/ton of limestone feed)	None (7)	0.0 (7)	0.0	0.0	0.0
NO_x					
Boiler ($lb/10^6$ Btu heat input)	0.7	0.75 (8)	0.7	6.7	6.7
Calciner (lb/ton of limestone feed)	None (9)	None	None	None	None

Emission	1979 NSPS Emission Limit Required for Compliance	Modified Reference Plant Design Value (10)			
		Potential Emission (11)	Reduced Emission	Percent Reduction (15)	
				Required	Provided
Particulates ($lb/10^6$ Btu heat input)	0.03	8.7 (12)	0.03	99.7	99.7
SO_2 ($lb/10^6$ Btu heat input)	0.72 (13)	8.3	0.83	90.0	90.0
NO_x ($lb/10^6$ Btu heat input)	0.6	0.75 (14)	0.6	20.0	20.0

*See pages 202 and 203 for explanation of footnotes

NOTES TO TABLE XXXI

(1) Based on Illinois No. 6 coal with a 9.6 percent (wt) design total ash (75 percent fly ash, 25 percent collected boiler slag and fly ash), 4.5 percent (by wt) design sulfur content (3.9 percent mean value), 10,788 Btu/lb design heat value.

(2) At the entrance to the ESP. Based on coal characteristics listed in Note 1 (0.096 lb total ash per lb. coal x 0.75 lb. fly ash per lb. total ash x 10^6/10,788 Btu per lb. coal).

(3) lb/ton of limestone feed at the entrance to the calciner baghouse. Based on coal characteristics listed in Note 1 and 13,810 pph of coal fired per 119,050 pph of limestone feed (Ref. A1, table 9, p. 29) (13,810 pph of coal x 0.096 lb. total ash per lb. coal x 0.75 lb. fly ash per lb. total ash x 2000 lb. per ton/119,050 pph of limestone).

(4) Leaving the electrostatic precipitator. This emission is assumed to be the same as that at the stack, where compliance measurements were to be carried out at the time of the ECAS study (Ref. A1).

(5) Calciner emissions were not specifically covered by New Source Performance Standards at the time the ECAS study was carried out (see, for example, Ref. A1). The calciner emissions, though, were probably expected to be similar to those of a Portland cement factory which were covered by a particulate emission limit of 0.30 lb/ton of feed, as listed. A baghouse was therefore included in the ECAS reference plant. Its efficiency was not specified, however.

(6) Excess scrubbing capability is included in the ECAS reference plant which reduces emissions below the 1.2 lb $SO_2/10^6$ Btu heat input limit required for coals with 3.9 to 4.5 percent (wt) sulfur content.

(7) No SO_2 emissions are produced by a direct coal-fired calciner. All the SO_2 generated by the coal combustion is trapped by the lime product. No additional controls are required.

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NOTES TO TABLE XXXI (Concluded)

(8) The ECAS report (Ref. A1) states that NO_x is controlled by staged combustion in the boiler. No additional controls were included. The value listed is typical of an uncontrolled high turbulence coal-fired burner design in about 1975.

(9) Calciner NO_x emissions are not covered by a New Source Performance Standard, since the calciner fuel combustion temperature is low enough to make NO_x production and emission insignificant.

(10) In contrast to the ECAS reference plant (Ref. A1), on-site calcination is not included in the modified reference plant.

(11) Based on the same Illinois No. 6 coal characteristics listed in Note 1 except for the design total ash content which is increased to 12.5 percent (wt) to conservatively allow for utilization of the alternate (ETF) coal which has a greater total ash content than the primary (ECAS) coal (see table II).

(12) At the entrance to the electrostatic precipitator. Based on the coal mean values listed in Note 11 (0.125 lb. ash per lb. coal x 0.75 lb. fly ash per lb. total ash x 10^6/10,788 Btu per lb. coal).

(13) 10 percent of the potential emissions (90 percent reduction), based on primary coal design sulfur content and heat value listed in Note 1.

(14) NO_x is controlled in the boiler. Maximum emissions are guaranteed by the manufacturer. The value listed is typical of an uncontrolled high turbulence coal-fired burner design in about 1975.

(15) Additional scrubbing capability is provided to account for coal composition variations and alternate coal utilization in the modified plant compared to the ECAS plant.

modified plant fuel. Thus, each of the design parameters of the modified plant is calculated (as shown in the notes to table II) as the ratio of a mean potential emission quantity plus 1 or 2 statistical standard deviations based on engineering judgment, to the mean fuel heat value.

Column 4 lists the reduced emissions provided by the emission controls applied to the ECAS and modified plants. For compliance, these must be less than or equal to the emission limits specified in Column 2. As may be seen, this is the case.

Column 5, broken into two parts, lists the percent reduction, corresponding to the ratio of the reduced emission to the potential emission, required to minimally comply with the applicable NSPS, and the percent reduction provided in the plant design. As is indicated, the ECAS plant design provided slightly more than the required NSPS percent reduction for particulates, and 4.5 percent excess reduction for sulfur dioxide. As discussed in section A5.0, nitrogen oxides were controlled to meet emission limits by internal boiler design. For comparative purposes, however, a typical value for an uncontrolled high turbulence coal-fired burner design in 1975 is listed. Similarly, the modified plant design provides the required 1979 NSPS percent reductions for particulates and sulfur dioxide. NO_x is again controlled by internal boiler design, and again for comparative purposes the same uncontrolled NO_x emission value is listed. No excess particulate or SO_2 reduction capability is provided in the modified plant design, since by definition, the modified plant design parameters are conservatively calculated to provide the necessary margin to account for expected fuel variations. It should be noted also that a significant part of the increase of the particulate reduction requirement above that required for the ECAS plant arises from the usual utility industry practice built into the modified plant to burn primary and alternate coals, as discussed in section 3.3 and section A1.0. This is in contrast to the ECAS plant which burns only one coal. The primary coal characteristics correspond to those specified in ECAS study, and the alternate

coal characteristics correspond to those specified in the Engineering Test Facility (ETF) study (Ref. 3). Since the alternate coal design total ash content (12.5 percent (by wt), mean plus 1 std. dev.) is considerably greater than that of the primary coal) 10.5 percent (by wt), the greater particulate reduction requirement for the modified plant was determined by the capability to utilize the alternate coal.

Appendix E

ECAS Reference Plant Detailed Capital Cost Estimates as of Mid-1975

This appendix contains the detailed cost estimates for the ECAS reference plant as of mid-1975, developed during the ECAS study (Ref. A1), recast in the format specified for this study. Table XXXII presents the 250° F (394° K) stack gas reheat case and table XXXIII presents the 175° F (353° K) stack gas reheat case. These estimates form the basis for the updated ECAS reference plant cost estimates, as of mid-1978, presented in sections 7.2 and 7.3.

TABLE XXXII. - ECAS REFERENCE CONVENTIONAL FURNACE COAL-FIRED POWER PLANT WITH WET SO_2 SCRUBBER CAPITAL COST ESTIMATE DETAILS AS OF MID-1975
(250° F Stack Gas Reheat Temperature (1))
(Mid-1975 Dollars)

FERC Account Number	ECAS Report Ident. No(s). (2)	Account/Subdivision		Material Costs		Installation Cost (3)	Indirect Cost (4)	Contingency Allowance (5)	Total Cost
		Title	Description/Specification	Major Component	Balance of Plant				
310.	-	LAND AND LAND RIGHTS	- - -			Not Included in Study			
311.	-	STRUCTURES AND IMPROVEMENTS (6)	Total Account 311.	-	11,341,000	10,607,500	9,549,960	6,299,692	37,798,152
311.1	7.0	Improvements to Site	Total Subdivision 311.1	-	1,420,000	3,063,250	2,740,220	1,440,694	8,664,164
311.11	7.1	Site Preparation and Improvements	Soil testing, clearing and grubbing, rough grading, finish grading, landscaping	-	10,000	1,022,250	920,460	390,542	2,343,252
311.12	7.2	Site Utilities	Storm and sanitary sewers, non-process service water	-	50,000	58,750	52,900	32,330	193,980
311.13	7.3	Roads and Railroads	Railroad spur, roads, walks and parking areas	-	740,000	317,250	285,660	268,582	1,611,492
311.14	7.4	Yard and Plant Fire Protection, Fences and Gates	- - -	-	600,000	611,000	550,160	352,232	2,113,392
311.15	7.5	Water Treatment Ponds	Earthwork, pond lining, off-site pipeline	-	20,000	1,034,000	931,040	397,008	2,382,048
311.3	-	Main (Turbine-Generator) Building	Total Subdivision 311.3	-	2,433,000	1,926,000	1,734,000	1,218,600	7,311,600
311.31	5.1,5.3	-	Excavation, substructure, de-watering and piling, including excavation and substructure for transmission plant switch-yard	-	-	-	-	-	-
311.32	5.2	-	Building structure and services	-	-	-	-	-	-
311.4	-	Steam Generator Building	Total Subdivision 311.4	-	5,972,000	4,727,000	4,256,000	2,991,000	17,946,000
311.41	5.1,5.3	-	Excavation, substructure, de-watering and piling	-	-	-	-	-	-
311.42	5.2	-	Enclosure structure and ser-vices	-	-	-	-	-	-

*See page 221 for explanation of footnotes

TABLE XXXII. - (Continued)

FERC Account Number	ECAS Report Ident. No(s).(2)	Account/Subdivision: Title	Account/Subdivision: Description/Specification	Material Costs: Major Component	Material Costs: Balance of Plant	Installation Cost (3)	Indirect Cost (4)	Contingency Allowance(5)	Total Cost
311.6	-	<u>Maintenance, Service, Warehouse and Office Building (Service Building)</u>	Total Subdivision 311.6	-	830,000	657,000	591,000	415,600	2,493,600
311.61	5.1,5.3	-	Excavation, substructure, dewatering and piling	-	-	-	-	-	-
311.62	5.2	-	Building Structure and services	-	-	-	-	-	-
311.7	5.1,5.3	<u>Other Buildings</u>	Total Subdivision 311.7 Excavation and structure for makeup water intake	-	221,000	175,000	158,000	110,800	664,800
311.8	3.7	<u>Cranes and Hoists</u>	Total Subdivision 311.8 Crane and accessories in turbine hall	-	410,000	35,250	31,740	95,398	572,388
311.9	5.1,5.2	<u>On-site Waste Treatment (Including Water Treatment) Building</u>	Total Subdivision 311.9 Excavation, substructure building structure and services; lime, alum, ion exchange resin, acid, caustic and chlorine storage tanks; reagent metering and feeding pumps; mixers; clarifiers	-	55,000	44,000	39,000	27,600	165,600

*See page 221 for explanation of footnotes

TABLE XXXII. - (Continued)

FERC Account Number	ECAS Report Ident. No(s).(2)	Account/Subdivision: Title	Account/Subdivision: Description/Specification	Material Costs: Major Component	Material Costs: Balance of Plant	Installation Cost (3)	Indirect Cost (4)	Contingency Allowance(5)	Total Cost
312.	-	BOILER PLANT (3)	Total Account 312.	45,880,000	60,619,000	27,944,500	25,162,929	31,921,284	191,527,734
312.1	3.8, 5.1, 5.3	Coal Handling	Total Subdivision 312.1	-	7,189,000	1,941,750	1,749,380	2,176,026	13,056,156
			Coal, limestone and ash handling excavations, foundations pits & tunnels. Also, railcar dumping equipment, dust collectors, primary & secondary crushing equipment, belt scale, sampling station, magnetic cleaners, mobile equipment, coal silos, reclaiming feeders, and the following conveyors to coal pile and coal silos:						
312.11	-	Unloading and Yard Storage	- - -	-	-	-	-	-	-
	C-1	Coal Conveyor belt	60 in. wide, 340 ft. long, 3000 tph	-	-	-	-	-	-
	C-2	Coal Conveyor belt	60 in. wide, 760 ft. long, 3000 tph	-	-	-	-	-	-
	C-3	Coal Conveyor belt	60 in. wide, 190 ft. long, 3000 tph	-	-	-	-	-	-
312.12	-	Reclaim and Delivery	- - -	-	-	-	-	-	-
	C-4	Coal Conveyor belt	42 in. wide, 980 ft. long, 500 tph	-	-	-	-	-	-
	C-5	Coal Conveyor belt	42 in. wide, 540 ft. long, 500 tph	-	-	-	-	-	-
	C-6	Coal Conveyor belt	42 in. wide, 170 ft. long, 500 tph	-	-	-	-	-	-
	C-7	Coal Conveyor belt	42 in. wide, 110 ft. long, 500 tph	-	-	-	-	-	-
	C-8	Coal Conveyor belt (2 reqd.)	30 in. wide, 160 ft. long, 300 tph	-	-	-	-	-	-

*See page 221 for explanation of footnotes

TABLE XXXII. - (Continued)

FERC Account Number	ECAS Report Ident. No(s).(2)	Account/Subdivision: Title	Account/Subdivision: Description/Specification	Material Costs: Major Component	Material Costs: Balance of Plant	Installation Cost (3)	Indirect Cost (4)	Contingency Allowance(5)	Total Cost
312.2	3.10	Slag and Ash Handling	Total Account 312.2	-	3,580,000	716,750	645,380	988,426	5,930,556
			Bottom ash system, fly ash handling system for precipitators and air pre-heater, ash conveyors, railcar loading equipment, ash hoppers, sluice pumps and drives, piping, clinker grinder, pressure blowers, valves and piping, and the following storage silos and associated equipment:						
312.21	C-16	Fly ash storage silos (2 reqd.)	Feeders, unloaders and foundations, silos: total volume 833,184 cu. ft., 85 ft. high, 80 ft. dia.	-	-	-	-	-	-
312.3	3.9	Limestone Handling	Total Subdivision 312.3	-	1,250,000	258,500	232,760	348,252	2,089,512
			Magnetic cleaners, reclaiming feeders, belt scale, and the following conveyors to limestone pile and calciner:						
312.31	-	Conveyors		-	-	-	-	-	-
	C-9	Limestone Conveyor belt	60 in. wide, 500 ft. long, 3000 tph	-	-	-	-	-	-
	C-10	Limestone Conveyor belt	24 in. wide, 630 ft. long, 65 tph	-	-	-	-	-	-
	C-11	Limestone Conveyor belt	24 in. wide, 420 ft. long, 65 tph	-	-	-	-	-	-
	C-12	Limestone bucket Conveyor	24 in. wide, 120 ft. long, 100 tph	-	-	-	-	-	-

*See page 221 for explanation of footnotes

TABLE XXXII. - (Continued)

FERC Account No.	ECAS Report Ident. No(s). (2)	Account/Subdivision		Material Costs		Installation Cost (3)	Indirect Cost (4)	Contingency Allowance (5)	Total Cost
		Title	Description/Specification	Major Component	Balance of Plant				
312.4	-	Steam Generator Equipment	Total Subdivision 312.4	39,730,000	13,380,000	14,769,750	13,299,060	16,235,762	97,414,572
312.41	1.1, Table 14	Steam Generator	Heat transfer surface and pressure parts; buckstays, braces and hangers; fuel-burning equipment, accessories, soot and ash equipment; control systems, brick-work, refractory and insulation; support steel & misc. materials; primary air fans & feedwater piping	39,730,000	6,800,000	9,870,000	8,887,200	13,057,440	78,344,640
312.42	6.7	Instrumentation and Controls	Integrated boiler controls boiler/turbine coordinating controls, main mech. system control boards, sampling system includ. analyzers and sampling panel, stack emissions monitoring system, and data acquisition system	-	4,900,000	2,585,000	2,327,600	1,962,520	11,775,120
312.43	1.2	Auxiliaries	Air preheater; flues and ducts to pre-cipitators; insulation for flues and ducts; pulverizers, feeders and hoppers; and the following fans:	-	1,680,000	2,314,750	2,084,260	1,215,802	7,294,812
	F-9	Forced draft fans (2 reqd. @ $390,000 ea.)	Operating: 971,000 cfm @ 80° F.S.P. outlet=19 in. w.g. Test block: 1,165,000 cfm @ 105° F.S.P. outlet=24.7 in. w.g. Motor: 6,500 hp	-	-	-	-	-	-

*See page 221 for explanation of footnotes

TABLE XXXII. - (Continued)

FPC Account Number	ECAS Report Ident. Note (2)	Account/Subdivision Title	Description/Specification	Material Costs Major Component	Material Costs Balance of Plant	Installation Cost (3)	Indirect Cost (4)	Contingency Allowance (5)	Total Cost
	F-10	Primary air fans (2 reqd.)	Operating: 161,750 cfm @ 96° F, S.P. inlet = 19 in. w.g., S.P. outlet = 42 in. w.g. Test Block: 194,000 cfm @ 121° F, S.P. inlet=19 in. w.g., S.P. outlet=54.6 in. w.g. Motor: 2,250 hp	Included in Subdivision 312.41					
	F-14	Induced draft fans (4 reqd. @ $220,000 ea.)	Operating: 660,000 cfm @ 300° F, Total S.P. = 23 in. w.g. Test block: 800,000 cfm @ 325° F, Total S.P. = 30 in. w.g. Motor: 5,000 hp	-	-	-	-	-	-
312.5	-	Auxiliary Boiler System	Optional (not included)	-	-	-	-	-	-
312.6	-	Other Boiler Plant Systems	Total Subdivision 312.6	-	6,930,000	282,000	253,920	1,493,184	8,959,104
312.61	-	Condensate and Feedwater System	Total Subdivision 312.61	-	6,930,000	282,000	253,920	1,493,184	8,959,104
	3.3, F-4	Main condensate pumps & motors (2 reqd. @ $85,000 ea.)	Vertical centerline, 4250 gpm, 600 hp motor, 410 ft. TDH (Other pumps and drivers not listed elsewhere)	-	650,000	58,750	52,900	152,330	913,980
	3.1, (7) F-5	Feedwater booster pumps and motors (2 reqd. @ $125,000 ea.)	7,300 gpm, 3850hp, 1510 ft. TDH	-	275,500	23,500	21,160	64,032	384,192
	3.1, (7) F-6	Main boiler feed pumps and turbine drives (3 reqd. @ $940,000 ea.)	4900 gpm, 12,600 hp, 8300 ft. TDH	-	2,944,500	94,000	84,640	624,628	3,747,768
	F-2	Boiler feedwater piping	- - - -	Included in Subdivision 314.41					
	3.5, F-3	Feedwater heaters	Miscellaneous heaters and exchangers; tanks and vessels; and the following low pressure (4), intermediate pressure (1) and deaerating feedwater (1) heaters:	-	3,060,000	105,750	95,220	652,194	3,913,164

*See page 221 for explanation of footnotes

TABLE XXXII. - (Continued)

FERC Account Number	ECAS Report Ident. No(s).(2)	Account/Subdivision		Material Costs		Installation Cost (3)	Indirect Cost (4)	Contingency Allowance (5)	Total Cost
		Title	Description/Specification	Major Component	Balance of Plant				
			Shell Press./Temp. psia/°F — Tube Press./Temp. psia/°F — Flow 100 percent lb/hr — Heat transfer area sq.ft. LP#1 5/163 — 210/158 — $4.05x10^6$ — 14,330 LP#2 11/195 — 210/199 — $4.05x10^6$ — 13,550 LP#3 20/228 — 210/223 — $4.05x10^6$ — 13,720 LP#4 67/300 — 210/295 — $4.05x10^6$ — 18,770 IP 296/416 — 1040/415 — $6.22x10^6$ — 45,660 HP 745/510 — 5700/519 — $6.22x10^6$ — 49,700 DFH $6.22x10^6$ lb/hr @ 353° F						
312.62	-	Water Treatment System	- - -	Included in Subdivision 311.9					
312.7	-	<u>Effluent Control</u>	Total Subdivision 312.7	6,150,000	4,880,000	2,855,250	2,570,940	3,291,230	19,747,420
312.71	1.3, F-11, Table 14	Precipitators and Breeching (4 reqd.)	Total Subdivision 312.71 54 ft. high x 92 ft. wide x 44 ft. long each, 1,262,000 lb, 1296 kVA, 99 percent particulate removal efficiency, 695,000 acfm @ 300° F, including support steel	6,150,000	220,000	1,210,250	1,089,740	1,733,998	10,403,988
312.72	3.6, F-16	Chimney	Total Subdivision 312.72 Concrete stack and liner; lights and marker painting; hoists and platforms; stack foundation 40 ft. I.D., 500 ft. high	-	1,570,000	1,327,750	1,195,540	818,650	4,911,940
312.73	-	Stack Gas Reheat System	Total Subdivision 312.73	-	3,090,000	317,250	285,660	738,582	4,431,492
	3.14, F-15 (8)	Forced draft fans for reheater air (6 reqd. @ $200,000 ea.)	Operating: 545,000 cfm @ 80° F, Total S.P. = 3.5 in. w.g. Test block: 654,000 cfm @ 105° F, Total S.P. = 4.55 in. w.g. Motor: 650 hp	-	1,305,000	152,750	137,540	319,050	1,914,340
	3.15, F-13 (8)	Stack gas reheat air heaters (6 reqd. @ $280,000 ea.)	4.5 ft. high, 21.5 ft. wide x 37.5 ft. long each	-	1,783,000	164,500	148,120	419,524	2,517,144

*See pages 221 and 222 for explanation of footnotes

TABLE XXXII. - (Continued)

FERC Account Number	ECAS Report Ident. No(s).(2)	Account/Subdivision		Material Costs		Installation Cost (3)	Indirect Cost(4)	Contingency Allowance(5)	Total Cost
		Title	Description/Specification	Major Component	Balance of Plant				
312.8	-	Flue Gas Desulfurization System	Total Subdivision 312.8	-	23,410,000	7,120,500	6,411,480	7,388,396	44,330,376
312.81	-	FGD Equipment	Total Subdivision 312.81	-	16,090,000	4,230,000	3,808,800	4,825,760	28,954,560
	3.15, F-12	Wet lime SO_2 scrubbers (turbulent contact absorber)(6 reqd. @ $1,000,000 ea)	Complete SO_2 scrubber vessels with pre-saturator and mist eliminator systems. 60ft. high x 40 ft. wide x 18ft. long, 316L stainless steel, neoprene lined, 3 stages, 450,000 acfm @ 312° F each	-	6,930,000	1,010,500	909,880	1,770,076	10,620,456
	3.13	Scrubber ductwork	Flue gas duct outboard of electro-static precipitators, duct lining, duct insulation, dampers & expansion joints	-	3,270,000	2,432,250	2,190,060	1,578,462	9,470,772
	3.17	Scrubber system pumps	Slurry recycle (18 @ $40,000 ea.); mist eliminator wash (3 @ $25,000 ea.); slurry storage and transfer (4 @ $4,000 ea.); slurry feed (3 @ $5,000 ea.); pond feed tank (3 @ $10,000 ea.); pond feed booster (2 @ $15,000 ea.); pond water recycle and booster (4 @ $12,500 ea.)	-	1,080,000	117,500	105,800	260,660	1,563,960
	3.18	Scrubber system tanks	Tanks and agitators for absorber effluent hold, pond feed, entrainment separator surge, slurry surge, slurry stor[illegible] and slurry tran[illegible]	-	2,180,000	47,000	42,320	453,864	2,723,184

*See page 221 for explanation of footnotes

TABLE XXXII. - (Continued)

FERC Account Number	ECAS Report Ident. No(s). (2)	Account/Subdivision		Material Costs		Installation Cost (3)	Indirect Cost(4)	Contingency Allowance (5)	Total Cost
		Title	Description/Specification	Major Component	Balance of Plant				
	6.2	Scrubber system large piping	Makeup water, re-saturation slurry water, mist eliminator wash, absorber slurry effluent tank overflow, pond feed, pond recycle water, lime slurry, recycle slurry, air heater steam, supply, and air heater condensate return piping	-	2,630,000	622,750	560,740	762,690	4,576,180
312.02	5.5	Foundations and Structural	Total Subdivision 312.02 Foundations earth-work and structures particular to scrubber equipment	-	3,660,000	2,115,000	1,904,400	1,535,880	9,215,280
312.03	3.16, C-13, C-14, C-15	Lime Manufacturing System (traveling grate kiln @ $2,700,000; lime slaker @ $120,000)	Total Subdivision 312.03 Limestone calciner: 650tons/day, nominal (800 tons/day, design), 12 ft. wide x 40ft. long traveling grate, 13ft. I.D. x 180ft. long rotary kiln with Niems-type cooler, coal conveyor, bucket elevator and storage bin, coal grinding/firing equipment, control panel/instrumentation, refractories, drives, induced draft fan, baghouse dust collector and ducting, kiln stack, lime conveyor bucket elevator, storage silos and lime slaker	-	3,660,000	775,500	698,280	1,026,756	6,160,536
	-	Limestone handling system excavations, foundations, conveyors, etc.	- - -	Included in Subdivisions 312.1 & 312.1					

*See page 221 for explanation of footnotes

TABLE XXXII. - (Continued)

FERC Account Number	ECAS Report Ident. No(s).(2)	Account/Subdivision: Title	Account/Subdivision: Description/Specification	Material Costs: Major Component	Material Costs: Balance of Plant	Installation Cost (3)	Indirect Cost (4)	Contingency Allowance(5)	Total Cost
314.	-	STEAM TURBINE - GENERATOR AND AUXILIARIES	Total Account 314.	26,000,000	19,560,000	14,781,500	13,309,640	14,730,228	88,381,368
314.1	2.0, Table 14, [illegible] 5 Table 24	Steam Turbine and Auxiliaries	Total Subdivision 314.1	26,000,000	100,000	1,410,000	1,269,600	5,755,920	34,535,520
			820 MW_e guaranteed generator output, tandem compound 4 flow turbine with 33.5 in. last stage buckets, 2.3" Hg abs ; 3500 psig/1000° F throttle steam, 1000° F/675 psig reheat steam; 15.4 percent continuous extraction for stack gas reheat; exciter; 992 MVA generator @ 75 psig hydrogen pressure; 0.9 pf Hydrogen, lube oil and seal oil systems, stopthrottle valves, cross-over piping, insulation, motors for auxiliaries.						
314.2	3.4, P-1	Condenser & Auxiliaries	Total Subdivision 314.2	-	2,120,000	188,000	169,280	495,456	2,972,736
			Shells, tubes, air ejectors at 2.3 in. Hg (abs.) 3.31×10^5 sq.ft. of heat transfer area, 3.93×10^6 pph						
314.3	-	Circulating Water System	Total Subdivision 314.3	-	4,310,000	1,703,750	1,534,100	1,509,570	9,057,420
314.31	-	Pumps, Valves, Piping and Structure	Total Subdivision 413.31	-	700,000	35,250	31,740	153,398	920,388
	3.2, P-7	Circulating water pumps and motors (3 @ $220,000)	82,000 gpm, 2250 hp, 75ft. TDH each	-	700,000	35,250	31,740	153,398	920,388
	5.4	Circulating water valves, piping & structure	- - -	Included in Subdivision 314.32					

*See page 221 for explanation of footnotes

TABLE XXXII. - (Continued)

FERC Account Number	ECAS Report Ident. No(s).(2)	Account/Subdivision: Title	Account/Subdivision: Description/Specification	Material Costs: Major Component	Material Costs: Balance of Plant	Installation Cost (3)	Indirect Cost (4)	Contingency Allowance (5)	Total Cost
314.32	-	Cooling Towers	Total Subdivision 314.32	-	3,610,000	1,668,500	1,5[illegible],360	1,356,172	8,137,832
	3.11, F-8	Tower Structure (20 cells)	Mechanical draft towers with fans and motors	-	2,230,000	611,000	550,160	678,232	4,069,392
	5.4, F-2	Tower basin & circulating water system	Circulating water pump pads, riser and concrete envelope for pipe; cooling tower basin; circulating water pipe (I.D. = 114 in.) & valves; misc. steel & fire protection. 246,000 gpm	-	1,380,000	1,057,500	952,200	677,940	4,067,640
314.4	-	**Steam Piping Systems**	Total Subdivision 314.4	-	11,370,000	11,127,250	10,019,260	6,503,302	39,019,812
314.41	6.1, F-2	Main Steam	Total Subdivision 314.41 Main steam (I. D. = 15.3 in., t_m=3.97 in); hot reheat (I.D.=18.1 in., t_m=2.25 in); cold reheat (I.D.=32.54 in., t_m=1.57 in); feedwater (I.D.=26.54 in., 0.675 in.) and condensate large piping, valves and fittings.	-	3,850,000	951,750	85[illegible],900	1,231,746	6,790,476
314.42	6.3	Auxiliary Steam	- - -	Included in Subdivision 314.43					
314.43	-	Miscellaneous Piping Systems	Total Subdivision 314.43	-	7,520,000	10,275,500	9,162,280	5,371,556	32,229,331
	6.3	Other large piping	Auxiliary steam, process water, auxiliary systems	-	4,050,000	2,714,250	2,443,980	1,841,640	11,049,876
	6.4	Small piping	All piping, valves and fittings of 2 in. diameter and less	-	1,350,000	1,786,000	1,[illegible],390	948,032	5,692,992
	6.5	Hangers and miscellaneous labor operations	All hangers and supports; material handling; scaffolding and associated miscellaneous labor operations	-	1,460,000	4,935,000	4,443,600	2,167,720	13,006,320
	6.6	Pipe insulation	- - -	-	660,000	760,250	866,540	413,350	2,480,140

*See page 221 for explanation of footnotes

TABLE XXXII. - (Continued)

FERC Account Number	ECAS Report Ident. No(s). (2)	Account/Subdivision Title	Description/Specification	Material Costs Major Component	Balance of Plant	Installation Cost (3)	Indirect Cost (4)	Contingency Allowance (5)	Total Cost
314.5	3.12	Other Turbine Plant & Mechanical Equipment	Total Subdivision 314.5	-	1,660,000	352,500	317,400	465,980	2,795,880
			Water treatment & chemical injection, air compressors & auxiliaries; fuel oil handling system, ignition & warmup; screenwell; misc. plant equipment & motors, & equipment insul.						
315.	-	ACCESSORY ELECTRIC EQUIPMENT	Total Account 315.	-	10,880,000	12,400,000	11,172,480	6,892,096	41,352,576
315.1	4-2	Station and Auxiliary Transformers	Total Subdivision 315.1	-	1,280,000	199,750	179,860	331,922	1,991,532
			Station service and startup transformers; service transformers for boiler and scrubber systems; generator main bus as follows:						
	E-2	Unit Auxiliary Transformers (2 reqd.)	40/54/67 MVA, 65° C, OA/FA/FOA, 24/13.8 kV, 3-phase, 60Hz	-	-	-	-	-	-
	E-4	Startup Transformer	28/37.5/47 MVA, OA/FA/FOA, 500/13.8 kV, 65° C, 3-phase 60Hz	-	-	-	-	-	-
	E-6	Boiler Auxiliary Transformers (2 reqd.)	5500 kVA, OA, 65° C, 13.8/4.16 kV, 3-phase, 60Hz	-	-	-	-	-	-
	E-8	Scrubber Transformers (2 reqd.)	5000 kVA, OA, 65° C, 13.8/4.16 kV, 3-phase, 60 Hz	-	-	-	-	-	-
315.2	-	Miscellaneous Motors	- - -	Included in Subdivision 314.5					

*See page 221 for explanation of footnotes

TABLE XXXII. - (Continued)

FERC Account Number	ECAS Report Notes* (2)	Account/Subdivision: Title	Account/Subdivision: Description/Specification	Material Costs: Major Component	Material Costs: Balance of Plant	Installation Cost (3)	Indirect Cost (4)	Contingency Allowance (5)	Total Cost
315.3	4.3	Switchgear & Motor Control Centers	Total Subdivision 315.3	-	3,400,000	493,500	444,360	[illegible]7,572	5,205,432
			Switchgear, switchyard & load centers; motor control centers; local control stations; distribution panels, relay & meter boards; & the following transformers:						
	E-5	Misc. 480 V load control center transformers (14 reqd.)	1689 kVA, OA, 65° C, 13.8kV/480 V/277 V, 3-phase, 60Hz	-	-	-	-	-	-
	E-7	Local control center transformers (2 reqd.)	7000 kVA, OA, 65° C, 13.8/4.16 kV, 3-phase, 60Hz	-	-	-	-	-	-
315.4	4.6	Conduit, Trays, Wire, Cable and Busswork	Total Subdivision 315.4	-	4,000,000	7,426,000	6,686,560	3,638,512	21,831,072
315.5	4.4	Miscellaneous Electrical Equipment	Total Subdivision 315.5		2,010,000	4,265,250	3,840,540	2,023,158	12,138,948
			Communications; grounding; cathodic & freeze protection; lighting; pre-operational testing						
315.6	-	Integrated Control System	- - -	Included in Subdivision 312.42					
315.7	-	Data Acquisition System	- - -	Included in Subdivision 312.42					
315.8	4.5, E-3	Emergency Power System	Total Subdivision 315.8	-	110,000	23,500	21,160	30,932	185,592
			Diesel generator, batteries & associated d.c. equipment. 1000 KW, 3-phase, 60 Hz, 480 V, 0.8 pf.						
316.	-	MISCELLANEOUS POWER PLANT EQUIPMENT	Total Account 316.	-	280,000	11,750	10,580	60,466	362,796
316.1	-	Fuel Oil Handling System	- - -	Included in Subdivision 314.5					
316.2	-	Fire Protection System	- - -	Included in Subdivision 311.14					
316.3	7.6	Machine & Maintenance Shops	- - -	-	280,000	11,750	10,580	60,466	362,796

*See page 221 for explanation of footnotes

TABLE XXXII. - (Concluded)

FERC Account Number	ECAS Report Ident. No(s) (2)	Account/Subdivision		Material Costs		Installation Cost (3)	Indirect Cost (4)	Contingency Allowance (5)	Total Cost
		Title	Description/Specification	Major Component	Balance of Plant				
350.	-	TRANSMISSION PLANT	Total Account 350.	-	2,020,000	47,000	42,320	421,864	2,531,184
350.1	5.1, 5.2, 5.3	Structures & Improvements	- - -	Included in Subdivision 311.3					
350.2	4.1, E-1	Main Transformers	Total Subdivision 350.2 468 MVA, FOA, 65°C, 24/500kV	-	2,020,000	47,000	42,320	421,864	2,531,184
350.3	4.3	Switchyard	- - -	Included in Subdivision 315.3					
		Total of Direct Accounts 310. to 350.		71,880,000	104,700,000	65,800,250	59,247,900	60,325,630	361,953,780
		A/E Services & Fee @ 18 percent of Balance of Plant Materials, Installation & Indirect Costs (9)							41,354,667
		Plant Capital Cost							403,308,447
		Escalation & Interest During Construction @ 54.8 percent (5.5 yr. Constr. per 6.5 percent escalation rates 10 percent interest rate) (10)							221,013,029
		Total Plant Capital Cost in Jan. 1981 Dollars							624,321,476
		Total Plant Capital Cost in mid-1975 Dollars (11)							441,555,635

*See pages 221 and 222 for explanation of footnotes

NOTES TO TABLE XXXII

(1) Based on ECAS report, tables 15 and 16 (Ref. A1).

(2) Identification numbers consisting of letters and numerals refer to table 15 of the ECAS report, reproduced in Appendix C pages 178 to 180, for reference. Identification numbers consisting of numerals only refer to table 16 of the ECAS report, reproduced in Appendix C pages 181 to 187, for reference. References to other ECAS report tables are as indicated.

(3) Based on $11.75 per direct field labor manhour, as employed in the ECAS report (Ref. A1, page 33).

(4) Based on $10.58 per direct field labor manhour (about 90 percent of the installation cost) as employed in the ECAS report (Ref. A1, page 33).

(5) Based on the 20 percent contingency rate included in the ECAS report (Ref. A1, page 44).

(6) The costs of the buildings, structures and excavations listed in Accounts 311.3, 311.4, 311.6, 311.7, 311.9 and 312.1 are calculated using the estimated percentages of the sum of the costs of Items 5.1, 5.2 and 5.3 of Ref. A1, table 16, listed in Appendix C, page 199, table XXX. See also page 181, table XXVII.

(7) The separate balance-of-plant materials costs for the feedwater booster (2) and main feedwater (3) pumps are estimated from the combined balance-of-plant materials cost of these five pumps ($3,220,000), listed in Ref. A1, table 16, as follows: The combined equipment cost of the pumps $3,070,000 ((2) x ($125,000) + (3)($940,000)) is subtracted from the combined balance-of-plant materials cost and the remainder ($150,000) divided by the total horsepower of the five pumps (45,500 hp) resulting in $3.30/hp. This cost per horsepower is then multiplied by the horsepower of the two feedwater booster pumps, for example, to give $25,410 (7700 hp x $3.30/hp) and the equipment cost of the two pumps, $250,000, added to the product to give $275,410. This figure is then rounded to $275,500. Similarly, the cost of the main feedwater

NOTES TO TABLE XXXII (Concluded)

pumps is estimated as \$2,944,740 (i.e., (\$3.30/hp) (38,700/hp) + 3(\$940,000)), which is rounded to \$2,944,500. The 10 MH combined direct labor manhours, also listed in Ref. A1, table 16, used for calculating the installation and indirect cost, is broken down according to the fraction of the total horsepower represented by the pumps. The feedwater booster pumps are thus allocated 2 MH ((7700 hp/45,500 hp) x 10, rounded to 2), and the main feedwater pumps 8 MH ((37,800 hp/45,500 hp) x 10, rounded to 8).

(8) The separate balance-of-plant materials costs for the stack gas reheat system forced draft fans and reheat air heaters are estimated from the combined \$3,090,000 balance-of-plant materials cost listed in Ref. A1, table 16, as follows: The combined equipment cost of the fans and heaters, \$2,880,000 (6x\$200,000 + 6x\$280,000), is subtracted from the combined balance-of-plant materials cost. The remainder, \$210,000, is divided equally between the fans and heaters, and one \$105,000 part is added to the equipment cost of the fans, the other to the equipment cost of the heaters, to give \$1,305,000 and \$1,785,000 for the respective balance-of-plant materials costs of each. The direct labor manhours are estimated to be 50 percent of the 27 MH listed, rounded to 13 MH, for the forced draft fans, and 50 percent of the 27 MH, rounded to 14 MH, for the reheat air heaters.

(9) Includes the 20 percent contingency in Note 5 applied to the 15 percent A/E services and fee rate employed in the ECAS report (Ref. A1, page 44) to account for the change in the order of applying the contingency and A/E Service and Fee rates in this study compared to the ECAS study.

(10) Based on the guidelines specified by NASA for the ECAS study (Ref. A6)

(11) The sum of the Plant Capital Cost and Escalation and Interest During Construction divided by $(1.065)^{5.5}$ to adjust the Total Plant Capital Cost in Jan. 1981 at the completion of the 5.5 year construction period to mid-1975 dollars.

TABLE XXXIII. - ECAS REFERENCE CONVENTIONAL FURNACE COAL-FIRED POWER PLANT WITH WET SO_2 SCRUBBER CAPITAL COST ESTIMATE DETAILS AS OF MID-1975
(175° F Stack Gas Reheat Temperature (1))
(Mid-1975 Dollars)

FERC Account Number	ECAS Report Ident. No(s). (2)	Account/Subdivision: Title	Account/Subdivision: Description/Specification	Material Costs: Major Component	Material Costs: Balance of Plant	Installation Cost (3)	Indirect Cost (4)	Contingency Allowance (5)	Total Cost
310.	-	LAND AND LAND RIGHTS	- - -			Not Included in Study			
311.	-	STRUCTURES AND IMPROVEMENTS (6)	Total Account 311.	-	11,341,000	10,607,500	9,549,960	6,299,692	37,798,152
311.1	7.0	Improvements to Site	Total Subdivision 311.1	-	1,420,000	3,043,250	2,740,220	1,440,694	8,644,164
311.11	7.1	Site Preparation and Improvements	Soil testing, clearing and grubbing, rough grading, finish grading, landscaping	-	10,000	1,022,250	920,460	390,542	2,343,252
311.12	7.2	Site Utilities	Storm and sanitary sewers, non-process service water	-	50,000	58,750	52,900	32,330	193,980
311.13	7.3	Roads and Railroads	Railroad spur, roads, walks and parking areas	-	740,000	317,250	285,660	268,582	1,611,492
311.14	7.4	Yard and Plant Fire Protection, Fences and Gates	- - -	-	600,000	611,000	550,160	352,232	2,113,392
311.15	7.5	Water Treatment Ponds	Earthwork, pond lining, off-site pipeline	-	20,000	1,034,000	931,040	397,008	2,382,048
311.3	-	Main (Turbine-Generator) Building	Total Subdivision 311.3	-	2,433,000	1,926,000	1,734,000	1,218,600	7,311,600
311.31	5.1,5.3	-	Excavation, substructure, de-watering and piling, including excavation and substructure for transmission plant switch-yard	-	-	-	-	-	-
311.32	5.2	-	Building structure and services	-	-	-	-	-	-
311.4	-	Steam Generator Building	Total Subdivision 311.4	-	5,972,000	4,727,000	4,256,000	2,991,000	17,946,000
311.41	5.1,5.3	-	Excavation, substructure, de-watering and piling	-	-	-	-	-	-
311.42	5.2	-	Enclosure structure and services	-	-	-	-	-	-

*See page 237 for explanation of footnotes

TABLE XXXIII. - (Continued)

FERC Account Number	ECAS Report Ident. No(s).(2)	Account/Subdivision		Material Costs		Installation Cost (3)	Indirect Cost (4)	Contingency Allowance(5)	Total Cost
		Title	Description/Specification	Major Component	Balance of Plant				
311.6	-	Maintenance, Service, Warehouse and Office Building (Service Building)	Total Subdivision 311.6	-	830,000	657,000	591,000	415,600	2,493,600
311.61	5.1,5.3	-	Excavation, substructure, dewatering and piling	-	-	-	-	-	-
311.62	5.2	-	Building Structure and services	-	-	-	-	-	-
311.7	5.1,5.3	Other Buildings	Total Subdivision 311.7 Excavation and structure for makeup water intake	-	221,000	175,000	158,000	110,800	664,800
311.8	3.7	Cranes and Hoists	Total Subdivision 311.8 Crane and accessories in turbine hall	-	410,000	35,250	31,740	95,398	572,388
311.9	5.1,5.2	On-site Waste Treatment (Including Water Treatment) Building	Total Subdivision 311.9 Excavation, substructure building structure and services; lime, alum, ion exchange resin, acid, caustic and chlorine storage tanks; reagent metering and feeding pumps; mixers; clarifiers	-	55,000	44,000	39,000	27,600	165,600

*See page 237 for explanation of footnotes

TABLE XXXIII. - (Continued)

FERC Account Number	ECAS Report Ident. No(s).(2)	Account/Subdivision: Title	Account/Subdivision: Description/Specification	Material Costs: Major Component	Material Costs: Balance of Plant	Installation Cost (3)	Indirect Cost (4)	Contingency Allowance(5)	Total Cost
312.	-	BOILER PLANT (3)	Total Account 312.	45,880,000	56,559,000	26,334,750	23,713,460	[illegible],497,442	182,984,652
312.1	3.8, 5.1, 5.3	Coal Handling	Total Subdivision 312.1	-	7,189,000	1,941,750	1,749,3[illegible]	2,176,026	13,056,15[illegible]
			Coal, limestone and ash handling excavations, foundations pits and tunnels. Also, railcar dumping equipment, dust collectors, primary and secondary crushing equipment, belt scale, sampling station, magnetic cleaners, mobile equipment, coal silos, reclaiming feeders, and the following conveyors to coal pile and coal silos:						
312.11	-	Unloading and Yard Storage	- - -	-	-	-	-	-	-
	C-1	Coal Conveyor belt	60 in. wide, 340 ft. long, 3000 tph	-	-	-	-	-	-
	C-2	Coal Conveyor belt	60 in. wide, 760 ft. long, 3000 tph	-	-	-	-	-	-
	C-3	Coal Conveyor belt	60 in. wide, 190 ft. long, 3000 tph	-	-	-	-	-	-
312.12	-	Reclaim and Delivery	- - -	-	-	-	-	-	-
	C-4	Coal Conveyor belt	42 in. wide, 980 ft. long, 500 tph	-	-	-	-	-	-
	C-5	Coal Conveyor belt	42 in. wide, 540 ft. long, 500 tph	-	-	-	-	-	-
	C-6	Coal Conveyor belt	42 in. wide, 170 ft. long, 500 tph	-	-	-	-	-	-
	C-7	Coal Conveyor belt	42 in. wide, 110 ft. long, 500 tph	-	-	-	-	-	-
	C-8	Coal Conveyor belt (2 reqd.)	30 in. wide, 160 ft. long, 300 tph	-	-	-	-	-	-

*See page 237 for explanation of footnotes

TABLE XXXIII. - (Continued)

FERC Account Number	ECAS Report Ident. (1),(2)	Account/Subdivision Title	Account/Subdivision Description/Specification	Material Costs Major Component	Material Costs Balance of Plant	Installation Cost (3)	Indirect Cost (4)	Contingency Allowance (5)	Total Cost
312.2	3.10	Slag and Ash Handling	Total Account 312.2	-	3,580,000	716,750	645,380	988,426	5,930,556
			Bottom ash system, fly ash handling system for precipitators and air preheater, ash conveyors, railcar loading equipment, ash hoppers, sluice pumps and drives, piping, clinker grinder, pressure blowers, valves and piping, and the following storage silos and associated equipment:						
312.21	C-16	Fly ash storage silos (2 reqd.)	Feeders, unloaders and foundations, silos: total volume 833,184 cu. ft., 85 ft. high, 80 ft. dia.	-	-	-	-	-	-
312.3	3.9	Limestone Handling	Total Subdivision 312.3	-	1,250,000	258,500	232,760	348,252	2,089,512
			Magnetic cleaners, reclaiming feeders, belt scale, and the following conveyors to limestone pile and calciner:						
312.31	-	Conveyors		-	-	-	-	-	-
	C-9	Limestone Conveyor belt	60 in. wide, 500 ft. long, 3000 tph	-	-	-	-	-	-
	C-10	Limestone Conveyor belt	24 in. wide, 630 ft. long, 65 tph	-	-	-	-	-	-
	C-11	Limestone Conveyor belt	24 in. wide, 420 ft. long, 65 tph	-	-	-	-	-	-
	C-12	Limestone bucket Conveyor	24 in. wide, 120 ft. long, 100 tph	-	-	-	-	-	-
312.4	-	Steam Generator Equipment	Total Subdivision 312.4	39,730,000	13,300,000	14,758,000	13,288,480	16,215,296	97,291,776
312.41	1.1, Table 14	Steam Generator	Heat transfer surface and pressure parts; buckstays, braces and hangers; fuel-burning equipment, accessories, soot and ash equipment; control systems, brickwork, refractory and insulation; support steel & misc. materials; primary air fans & feedwater piping	39,730,000	6,800,000	9,870,000	8,887,200	13,057,440	78,344,640

*See page 237 for explanation of footnotes

TABLE XXXIII. - (Continued)

FERC Account Number	ECAS Report Ident. No(s).(2)	Account/Subdivision Title	Account/Subdivision Description/Specification	Material Costs Major Component	Material Costs Balance of Plant	Installation Cost (3)	Indirect Cost (4)	Contingency Allowance (5)	Total Cost
312.42	C.7	Instrumentation and Controls	Integrated boiler controls, boiler/turbine coordinating controls, main mech. system control boards, sampling system includ. analyzers and sampling panel, stack emissions monitoring system and data acquisition system	-	4,820,000	2,573,250	2,317,62[illegible]	1,942,054	11,652,[illegible]24
312.43	1.2	Auxiliaries	Air preheater; flues and ducts to precipitators; insulation for flues and ducts; pulverizers, feeders and hoppers; and the following fans:	-	1,680,000	2,314,750	2,084,260	1,215,802	7,294,812
	F-9	Forced draft fans (2 reqd. @ $390,000 ea.)	Operating: 971,000 cfm @ 80° F, S.P. outlet = 19 in. w.g. Test block: 1,165,000 cfm @ 105° F, S.P. outlet = 24.7 in. w.g. Motor: 6,500 hp	-	-	-	-	-	-
	F-10	Primary air fans (2 reqd.)	Operating: 161,750 cfm @ 96°F, S.P. inlet = 19 in. w.g., S.P. outlet = 42 in. w.g. Test Block: 194,000 cfm @ 121° F, S.P. inlet = 19 in. w.g., S.P. outlet = 54.6 in. w.g. Motor: 2,250 hp	(Included in Subdivision 312.41)					
	F-14	Induced draft fans (4 reqd. @ $220,000 ea.)	Operating: 660,000 cfm @ 300° F Total S.P. = 23 in. w.g. Test block: 800,000 cfm @ 325° F, Total S.P. = 30 in. w.g. Motor: 5,000 hp	-	-	-	-	-	-

*See page 237 for explanation of footnotes

TABLE XXXIII. - (Continued)

FERC Account Number	ECAS Report Ident. No(s), (2)	Account/Subdivision: Title	Account/Subdivision: Description/Specification	Material Costs: Major Component	Material Costs: Balance of Plant	Installation Cost (3)	Indirect Cost (4)	Contingency Allowance (5)	Total Cost
312.5	-	Auxiliary Boiler System	Optional (not included)	-	-	-	-	-	-
312.6	-	Other Boiler Plant Systems	Total Subdivision 312.6	-	7,050,000	282,000	253,920	1,517,184	9,103,104
312.61	-	Condensate and Feedwater System	Total Subdivision 312.61	-	7,050,000	282,000	253,920	1,517,184	9,103,104
	3.1, P-4	Main condensate pumps & motors (2 reqd. @ $95,000 ea.)	Vertical centerline, 510 gpm, 750 hp motor, 410 ft. TDH (Other pumps and drivers not listed elsewhere)	-	670,000	58,750	52,900	156,330	937,980
	3.1, P-5 (7)	Feedwater booster pumps and motors (2 reqd. @ $125,000 ea.)	7,300 gpm, 3850hp, 1510 ft. TDH	-	275,500	23,300	21,160	64,032	384,192
	3.1, P-6 (7)	Main boiler feed pumps and turbine drives (3 reqd. @ $940,000 ea.)	4900 gpm, 12,600 hp, 8300 ft. TDH	-	2,944,500	94,000	84,640	624,628	3,747,768
	P-2	Boiler feedwater piping	- - -	Included in Subdivision 314.41					
	3.5, P-3	Feedwater heaters	Miscellaneous heaters and exchangers; tanks and vessels; and the following low pressure (4), intermediate pressure (1) and deaerating feedwater (1) heaters:	-	3,160,000	105,750	95,220	672,194	4,033,164

	Shell Press./Temp. psia/°F	Tube Press./Temp. psia/°F	Flow 100 percent lb/hr	Heat transfer area sq.ft.
LP01	5/163	210/158	4.75x10^6	17,170
LP02	11/195	210/190	4.75x10^6	16,260
LP03	20/228	210/223	4.75x10^6	16,600
LP04	67/300	210/295	4.75x10^6	22,710
IP	296/416	1040/415	6.22x10^6	45,660
HP	745/510	5700/519	6.22x10^6	49,700
DFH	6.22x10^6 lb/hr @ 353°F			

312.[illegible]	-	Water Treatment System	- - -	Included in Subdivision 311.9					
312.7	-	Effluent Control	Total Subdivision 312.7	6,150,000	2,360,000	2,303,000	2,073,64[illegible]	2,577,3[illegible]	15,464,016

*See page 237 for explanation of footnotes

TABLE XXXIII. - (Continued)

FERC Account Number	ECAS Report Ident. No(s).(2)	Account/Subdivision Title	Account/Subdivision Description/Specification	Material Costs: Major Component	Material Costs: Balance of Plant	Installation Cost (3)	Indirect Cost (4)	Contingency Allowance (5)	Total Cost
312.71	1.3, F-11, Table 14	Precipitators and Breeching (4 reqd.)	Total Subdivision 312.71 54 ft. high x 92 ft. wide x 44 ft. long each, 1,262,000 lb, 1296 kVA, 99 percent particulate removal efficiency, 695,000 acfm @ 300° F, including support steel	6,150,000	220,000	1,210,250	1,089,740	1,733,998	10,403,988
312.72	3.6, F-16	Chimney	Total Subdivision 312.72 Concrete stack and liner; lights and marker painting; hoists and platforms; stack foundation 27 ft. I.D., 500 ft. high	-	1,240,000	1,010,500	909,880	632,076	3,792,456
312.73	-	Stack Gas Reheat System	Total Subdivision 312.73	-	900,000	82,250	74,060	211,262	1,267,572
	3.14, F-15 (8)	Forced draft fans for reheater air (6 reqd. @ $85,000 ea.)	Operating: 123,000 cfm @ 80° F, Total S.P. = 3.5 in. w.g. Test block: 147,000 cfm @ 105° F, Total S.P. = 4.55 in. w.g. Motor: 150 hp	-	555,000	35,250	31,740	124,398	746,388
	3.14, F-13 (8)	Stack gas reheat air heaters (6 required @ $50,000 ea.)	2.5 ft. high, 18.2 ft. wide x 10.7 ft. long each	-	345,000	47,000	42,320	86,864	521,184

*See pages 237 and 238 for explanation of footnotes

TABLE XXXIII. - (Continued)

FERC Account Number	ECAS Report Ident. No(s). (2)	Account/Subdivision: Title	Account/Subdivision: Description/Specification	Material Costs: Major Component	Material Costs: Balance of Plant	Installation Cost (3)	Indirect Cost(4)	Contingency Allowance (5)	Total Cost
312.8	-	Flue Gas Desulfurization System	Total Subdivision 312.8	-	21,830,000	6,074,750	5,469,860	6,674,922	40,049,532
312.81	-	FGD Equipment	Total Subdivision 312.81	-	14,510,000	3,184,250	2,867,180	4,112,286	24,673,716
	3.15, F-12	Wet lime SO_2 scrubbers (turbulent contact absorber (6 reqd. @ $1,000,000 ea)	Complete SO_2 scrubber vessels with presaturator and mist eliminator systems. 60ft. high x 40 ft. wide x 18ft. long, 316L stainless steel, neoprene lined, 3 stages, 450,000 acfm @ 312° F each	-	6,930,000	1,010,500	909,880	1,770,076	10,620,456
	3.13	Scrubber ductwork	Flue gas duct outboard of electrostatic precipitators, duct lining, duct insulation, dampers & expansion joints	-	1,950,000	1,410,000	1,269,600	925,920	5,555,520
	3.17	Scrubber system pumps	Slurry recycle (18 @ $40,000 ea.); mist eliminator wash (3 @ $25,000 ea.); slurry storage and transfer (4 @ $4,000 ea.); slurry feed (3 @ $5,000 ea.); pond feed tank (3 @ $10,000 ea.); pond feed booster (2 @ $15,000 ea.); pond water recycle and booster (4 @ $12,500 ea.)	-	1,080,000	117,500	105,800	260,660	1,563,960
	3.18	Scrubber system tanks	Tanks and agitators for absorber effluent hold, pond feed, entrainment separator surge, slurry surge, slurry storage and slurry transfer	-	2,180,000	47,000	42,320	453,864	2,723,184

*See page 237 for explanation of footnotes

TABLE XXXIII. - (Continued)

FERC Account Number	ECAS Report Ident. No(s). (2)	Account/Subdivision Title	Description/Specification	Material Costs Major Component	Material Costs Balance of Plant	Installation Cost (3)	Indirect Cost(4)	Contingency Allowance(5)	Total Cost
	6.2	Scrubber system large piping	Makeup water, re-saturation slurry water, mist eliminator wash, absorber slurry effluent tank overflow, pond feed, pond recycle water, lime slurry, recycle slurry, air heater steam, supply, and air heater condensate return piping	-	2,370,000	599,250	539,590	701,766	4,210,596
312.82	5.5	Foundations and Structural	Total Subdivision 312.82	-	3,660,000	2,115,000	1,904,400	1,535,880	9,215,280
			Foundations earth-work and structures particular to scrubber equipment						
312.83	3.16, C-13, C-14, C-15	Lime Manufacturing System (traveling grate kiln @ $2,700,000; lime slaker @ $120,000)	Total Subdivision 312.83	-	3,660,000	775,500	698,280	1,026,756	6,160,536
			Limestone calciner: 650tons/day, nominal (880 tons/day, design), 12 ft. wide x 48ft. long traveling grate, 13ft. I.D. x 180ft. long rotary kiln with Niems-type cooler, coal conveyor, bucket elevator and storage bin, coal grinding/firing equipment, control panel/instrumentation, refractories, drives, induced draft fan, baghouse dust collector and ducting, kiln stack, lime conveyor bucket elevator, storage silos and lime slaker						
	-	Limestone handling system excavations, foundations, conveyors, etc.	- - -	Included in Subdivisions 312.1 & 312.1					

*See page 237 for explanation of footnotes

TABLE XXXIII. - (Continued)

FERC Account Number	ECAS Report Ident. No(s). (2)	Account/Subdivision: Title	Account/Subdivision: Description/Specification	Material Costs: Major Component	Material Costs: Balance of Plant	Installation Cost (3)	Indirect Cost (4)	Contingency Allowance (5)	Total Cost
314.	-	STEAM TURBINE - GENERATOR AND AUXILIARIES	Total Account 314.	26,750,000	20,520,000	15,040,000	13,542,400	15,170,480	91,022,880
314.1	2.0, Fig., 5 Table 24	Steam Turbine and Auxiliaries	Total Subdivision 314.1	26,750,000	100,000	1,410,000	1,269,600	5,905,920	35,435,520
			869 MW_e guaranteed generator output; tandem compound 4 flow turbine with 33.5 in. last stage buckets 2.3" Hg abs; 3500 psig/1000° F throttle steam, 1000° F/675 psig reheat steam; 3.5 percent continuous extraction for stack gas reheat exciter, 992 MVA generator @ 75 psig hydrogen pressure; 0.9 pf. Hydrogen, lube oil and seal oil systems, stop-throttle valves, cross-over piping, insulation motors for auxiliaries						
314.2	3.4, P-1	Condenser & Auxiliaries	Total Subdivision 314.2	-	2,440,000	199,750	179,860	563,922	3,383,532
			Shells, tubes, air ejectors at 2.3 in. Hg (abs.), 3.97 x 10^5 sq.ft. of heat transfer area, 4.67x10^6 pph						
314.3	-	Circulating Water System	Total Subdivision 314.3	-	5,010,000	1,974,000	1,777,440	1,752,288	10,513,728
314.31	-	Pumps, Valves, Piping and Structure	Total Subdivision 413.31	-	750,000	35,250	31,740	163,398	980,388
	3.2, P-7	Circulating water pumps and motors (3 @ $235,000)	95,000 gpm, 2500 hp, 75 ft. TDH each	-	750,000	35,250	31,740	163,398	980,388
	5.4	Circulating water valves, piping & structure	- - -	Included in Subdivision 314.32					

*See page 237 for explanation of footnotes

TABLE XXXIII. - (Continued)

FERC Account Number	ECAS Report Ident. No(s).(2)	Account/Subdivision: Title	Account/Subdivision: Description/Specification	Material Costs: Major Component	Material Costs: Balance of Plant	Installation Cost (3)	Indirect Cost (4)	Contingency Allowance (5)	Total Cost
314.32	-	Cooling Towers	Total Subdivision 314.32	-	4,260,000	1,938,750	1,745,700	1,588,890	9,533,340
	3.11, F-5	Tower Structure (20 cells)	Mechanical draft towers with fans and motors	-	2,580,000	705,000	634,800	783,960	4,703,760
	5.4, F-2	Tower basin & circulating water system	Circulating water pump pads, riser and concrete envelope for pipe; cooling tower basin; circulating water pipe (I.D. = 123 in.) & valves; misc. steel & fire protection. 246,000 gpm	-	1,680,000	1,233,750	1,110,900	804,930	4,829,580
314.4	-	Steam Piping Systems	Total Subdivision 314.4	-	11,310,000	11,103,750	9,998,100	6,482,370	38,894,220
314.41	6.1, F-2	Main Steam	Total Subdivision 314.41 Main steam (I.D. = 15.3 in., t_m=3.97in.); hot reheat (I.D.=18.1 in., t_m=2.25 in.); cold reheat (I.D.=32.54 in., t_m=1.57 in.); feedwater (I.D.=26.53 in., 0.675 in.) and condensate large piping, valves and fittings.	-	3,850,000	951,750	856,980	1,131,746	6,790,476
314.42	6.3	Auxiliary Steam	- - -	Included in Subdivision 314.43					
314.43	-	Miscellaneous Piping Systems	Total Subdivision 314.43	-	7,460,000	10,152,000	9,141,120	5,350,624	32,103,744
	6.3	Other large piping	Auxiliary steam, process water, auxiliary systems	-	4,050,000	2,714,250	2,443,980	1,841,646	11,049,876
	6.4	Small piping	All piping, valves and fittings of 2 in. diameter and less	-	1,350,000	1,786,000	1,608,160	948,832	5,692,992
	6.5	Hangers and miscellaneous labor operations	All hangers and supports; material handling; scaffolding and associated miscellaneous labor operations	-	1,420,000	4,923,250	4,433,020	2,155,254	12,931,524
	6.6	Pipe insulation	- - -	-	640,000	728,500	656,960	404,892	2,429,352

*See page 237 for explanation of footnotes

TABLE XXXIII. - (Continued)

FERC Account Number	ECAS Report Ident. No(s).(2)	Account/Subdivision: Title	Account/Subdivision: Description/Specification	Material Costs: Major Component	Material Costs: Balance of Plant	Installation Cost (3)	Indirect Cost (4)	Contingency Allowance(5)	Total Cost
314.5	3.12	Other Turbine Plant & Mechanical Equipment	Total Subdivision 314.5	-	1,660,000	352,500	317,400	465,980	2,795,880
			Water treatment & chemical injection, air compressors & auxiliaries; fuel oil handling system, ignition & warmup; screenwell; misc. plant equipment & motors, & equipment insul.						
315.	-	ACCESSORY ELECTRIC EQUIPMENT	Total Account 315.	-	10,880,000	12,408,000	11,172,480	6,392,09[illegible]	41,352,576
315.1	4-2	Station and Auxiliary Transformers	Total Subdivision 315.1	-	1,280,000	199,750	179,860	331,922	1,991,532
			Station service and startup transformers; service transformers for boiler and scrubber systems; generator main bus as follows:						
	E-3, 4	Unit Auxiliary Transformers (2 reqd.)	40/54/67 MVA, 65° C, OA/FA/FOA, 24/13.8 kV, 3-phase, 60Hz	-	-	-	-	-	-
	E-6	Startup Transformer	.8/37.5/47 MVA, OA/FA/FOA, 500/13.8 kV, 65° C, 3-phase 60Hz	-	-	-	-	-	-
	E-21, 22	Boiler Auxiliary Transformers (2 reqd.)	5500 kVA, OA, 65° C, 13.8/4.16 kV, 3-phase, 60Hz	-	-	-	-	-	-
	E-25, 26	Scrubber Transformers (2 reqd.)	5000 kVA, OA, 65° C, 13.8/4.16 kV, 3-phase, 60 Hz	-	-	-	-	-	-
315.2	-	Miscellaneous Motors	- - -	Included in Subdivision 314.5					
315.3	4.3	Switchgear & Motor Control Centers	Total Subdivision 315.3	-	3,400,000	493,500	444,360	867,572	5,205,432
			Switchgear, switchyard & load centers; motor control centers; local control stations; distribution panels, relay & meter boards & the following transformers:						

*See page 237 for explanation of footnotes

TABLE XXXIII. - (Continued)

FERC Account Number	ECAS Report Ident. No. (2)	Account/Subdivision: Title	Account/Subdivision: Description/Specification	Material Costs: Major Component	Material Costs: Balance of Plant	Installation Cost (3)	Indirect Cost (4)	Contingency Allowance (5)	Total Cost
	E-[illegible]	Misc. 480 V load control center transformers (14 reqd.)	1689 kVA, OA, 65° C, 13.8kV/480 V/277 V, 3-phase, 60Hz	-	-	-	-	-	-
	E-[illegible], 24	Local control center transformers (2 reqd.)	7000 kVA, OA, 65° C, 13.8/4.16 kV, 3-phase, 60Hz	-	-	-	-	-	-
315.4	4.6	Conduit, Cable Tray, Wire, Cable and Busswork	Total Subdivision 315.4	-	4,080,000	7,426,000	6,686,560	3,638,51[illegible]	21,831,072
315.5	4.4	Miscellaneous Electrical Equipment	Total Subdivision 315.5	-	2,010,00[illegible]	4,[illegible]	3,840,54[illegible]	2,023,158	12,138,948
			Communications; grounding; cathodic & freeze protection; lighting; pre-operational testing						
315.6	-	Integrated Control System	- - -	Included in Subdivision 312.42					
315.7	-	Data Acquisition System	- - -	Included in Subdivision 312.42					
315.8	4.5, E-5	Emergency Power System	Total Subdivision 315.8	-	110,000	23,500	21,160	30,932	185,592
			Diesel generator, batteries & associated d.c. equipment. 1000 KW, 3-phase, 60 Hz, 480 V, 0.8 pf.						
316.	-	MISCELLANEOUS POWER PLANT EQUIPMENT	Total Account 316.	-	280,000	11,750	10,580	60,466	362,796
316.1	-	Fuel Oil Handling System	- - -	Included in Subdivision 314.5					
316.2	-	Fire Protection System	- - -	Included in Subdivision 311.14					
316.3	7.6	Machine & Maintenance Shops	- - -	-	280,000	11,750	10,580	60,466	362,796

*See page 237 for explanation of footnotes

TABLE XXXIII. - (Concluded)

FERC Account Number	ECAS Report Ident. No(s). (2)	Account/Subdivision: Title	Account/Subdivision: Description/Specification	Material Costs: Major Component	Material Costs: Balance of Plant	Installation Cost (3)	Indirect Cost (4)	Contingency Allowance (5)	Total Cost
350.	-	TRANSMISSION PLANT	Total Account 350.	-	2,020,000	47,000	42,320	421,864	2,531,184
350.1	5.1, 5.2, 5.3	Structures & Improvements	- - -	Included in Subdivision 311.3					
350.2	4.1, E-1.2	Main Transformers	Total Subdivision 350.2 458 MVA, FOA, 65°C, 24/500 kV	-	2,020,000	47,000	42,320	421,864	2,531,184
350.3	4.3	Switchyard	- - -	Included in Subdivision 315.3					
		Total of Direct Accounts 310. to 350.		72,630,000	101,600,000	64,449,000	59,031,200	59,342,040	356,052,240
		A/E Services & Fee @ 18 percent of Balance of Plant Materials, Installation & Indirect Costs (9)							40,334,436
		Plant Capital Cost							396,386,676
		Escalation & Interest During Construction @ 54.8 percent (5.5 yr. Constr. per 6.5 percent escalation rate 10 percent interest rate) (10)							217,219,898
		Total Plant Capital Cost in Jan. 1981 Dollars							613,606,574
		Total Plant Capital Cost in mid-1975 Dollars (11)							433,977,448

*See pages 237 and 238 for explanation of footnotes

NOTES TO TABLE XXXIII

(1) Based on ECAS report tables 27 and 28 (Ref. A1).

(2) Identification numbers consisting of letters and numerals refer to table 27 of the ECAS report, reproduced in Appendix C pages 188 to 191, for reference. Identification numbers consisting of numerals only refer to table 28 of the ECAS report, reproduced in Appendix C pages 192 to 198, for reference. References to other ECAS report tables are as indicated.

(3) Based on $11.75 per direct field labor manhour, as employed in the ECAS report (Ref. A1, page 33).

(4) Based on $10.58 per direct field labor manhour (about 90 percent of the installation cost) as employed in the ECAS report (Ref. A1, page 33).

(5) Based on the 20 percent contingency rate included in the ECAS report (Ref. A1, page 44).

(6) The costs of the buildings, structures and excavations listed in Accounts 311.3, 311.4, 311.6, 311.7, 311.9 and 312.1 are calculated using the estimated percentages of the sum of the costs of Items 5.1, 5.2 and 5.3 of Ref. A1, table 28, listed in Appendix C, page 199, table XXX. Note that the same table applies to both the 250° and 175° F (394° and 353° K) reheat cases.

(7) The separate balance-of-plant materials costs for the feedwater booster (2) and main feedwater (3) pumps are estimated from the combined balance-of-plant materials cost of these five pumps ($3,220,000), listed in Ref. A1, table 28, as follows: The combined equipment cost of the pumps $3,070,000 ((2)($125,000) + (3) ($940,000)) is subtracted from the combined balance-of-plant materials cost and the remainder ($150,000) divided by the total horsepower of the five pumps (45,500 hp) resulting in $3.30/hp. This cost per horsepower is then multiplied by the horsepower of the two feedwater booster pumps, for example, to give $25,410 (7700 hp x $3.30/hp) and the equipment cost of the two pumps, $250,000, added to the product to give $275,410. This figure is then rounded to

NOTES TO TABLE XXXIII (Concluded)

$275,500. Similarly, the cost of the main feedwater pumps is estimated as $2,944,740 (i.e., ($3.30/hp)(38,700 hp) + 3($940,000)), which is rounded to $2,944,500.

The 10 MH combined direct labor manhours, also listed in Ref. A1, table 28, used for calculating the installation and indirect costs, is broken down according to the fraction of the total horsepower represented by the pumps. The feedwater booster pumps are thus allocated 2 MH ((7700 hp/45,500 hp) x 10, rounded to 2) and the main feedwater pumps 8MH ((37,800 hp/45,500 hp) x 10, rounded to 8).

(8) The separate balance-of-plant materials costs for the stack gas reheat system forced draft fans and reheat air heaters are estimated from the combined $900,000 balance-of-plant materials cost listed in Ref. A1, table 28, as follows: The combined equipment cost of the fans and heaters, $810,000 (6x$85,000 + 6x$50,000), is subtracted from the combined balance-of-plant materials cost. The remainder, $90,000 is divided equally between the fans and heaters, and one $45,000 part is added to the equipment cost of the fans and the other to the equipment cost of the heaters to give $555,000 and $345,000 for the respective balance-of-plant materials costs of each. The direct labor manhours are estimated to be 50 percent of the 7 MH listed, rounded to 3 MH, for the forced draft fans, and 50 percent of the 27 MH, rounded to 4 MH, for the reheat air heaters.

(9) Includes the 20 percent contingency in Note 5 applied to the 15 percent A/E services and fee rate employed in the ECAS report (Ref. A1, page 44) to account for the change in the order of applying the contingency and A/E services and fee rates in this study compared to the ECAS study.

(10) Based on the guidelines specified by NASA for the ECAS study (Ref. A6,

(11) The sum of the Plant Capital Cost and Escalation and Interest During Construction divided by $(1.065)^{5.5}$ to adjust the Total Plant Capital Cost in Jan. 1981 at the completion of the 5.5 year construction period to mid-1975 dollars.

Appendix F

Appendix References

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